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Stefanchik et al.

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(54) **PATIENT-REFERENCED SURGICAL SUPPORT FRAME**

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(73) Assignee: **Ethicon Endo-Surgery, Inc.**, Cincinnati, OH (US)

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(52) **U.S. Cl.**

CPC ***A61B 19/26*** (2013.01); ***A61B 17/3417*** (2013.01); *A61B 2017/00535* (2013.01); *A61B 2017/00876* (2013.01); *A61B 2017/00991* (2013.01); *A61B 2017/347* (2013.01); *A61B 2017/3447* (2013.01)

(58) **Field of Classification Search**

CPC A61B 1/313; A61B 1/3132; A61B 1/3135; A61B 1/317; A61B 2017/3445; A61B 2017/3447; A61B 1/32; A61B 2017/3464–2017/3466; A61B 2017/347; A61B 17/3462

USPC 600/201–249; 606/53–60, 1, 96, 98, 606/108, 130, 114, 115

See application file for complete search history.

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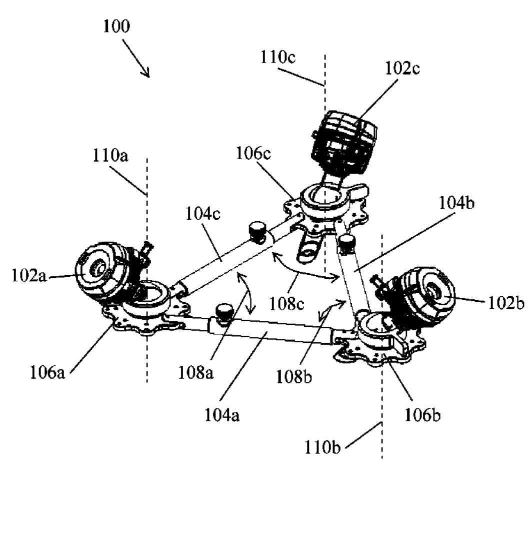
(57) **ABSTRACT**

A patient-referenced surgical support frame and method of use are provided. In one embodiment, a surgical support frame can have at least three support members coupled by adjustable linkages. Each support member can have a lumen extending therethrough for receiving a cannula, and each support member can be configured such that the at least three support members (or the cannulas extending therethrough) are angularly adjustable relative to one another, and such that a distance between each of the at least three support members is adjustable. In use, the surgical support frame can be positioned on a skin surface of a patient and used to retain one or more instruments extending through the support members in a fixed orientation or position with respect to the patient, thereby allowing more than two instruments to be used simultaneously.

13 Claims, 29 Drawing Sheets



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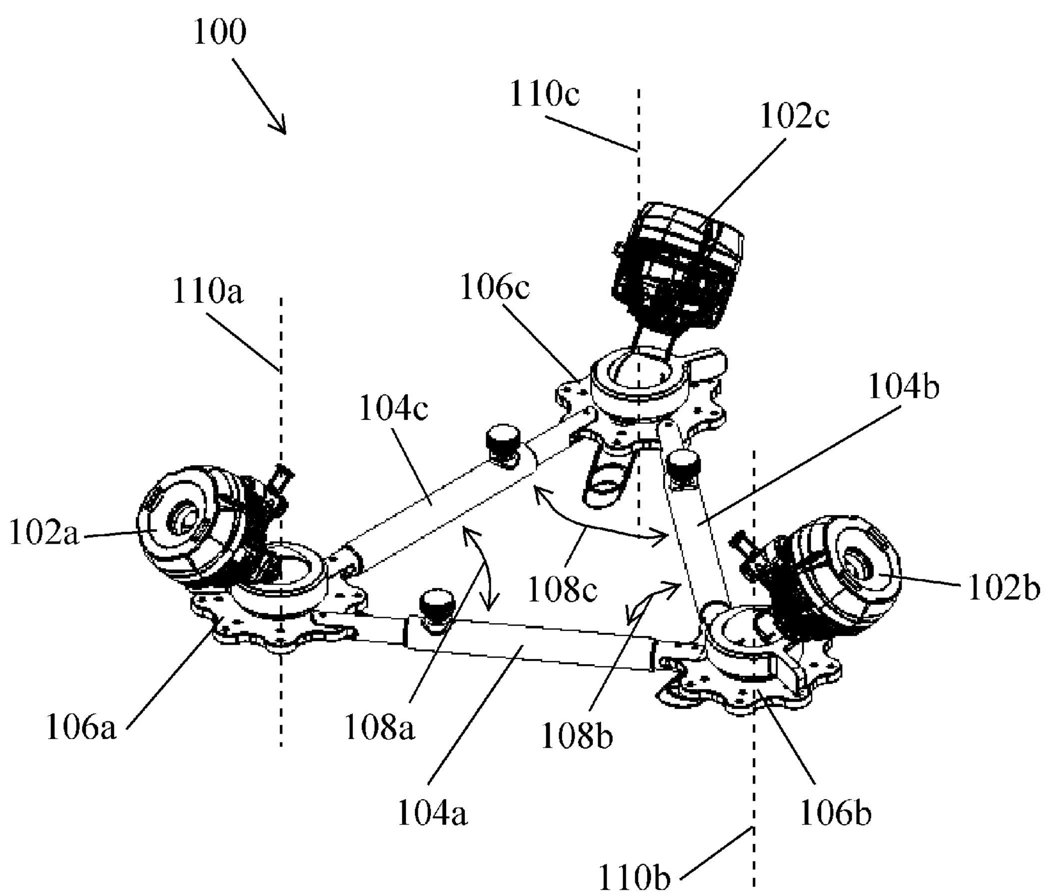
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FIGURE 1

FIGURE 2a

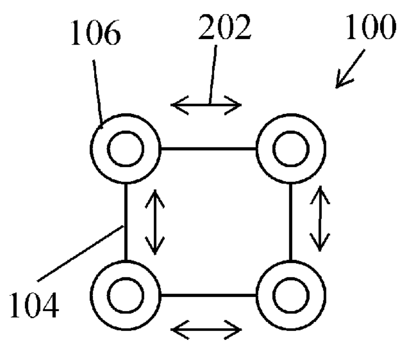
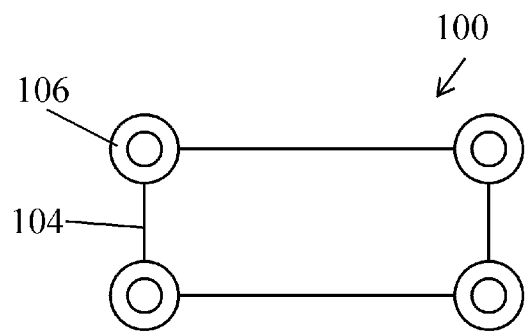


FIGURE 2b



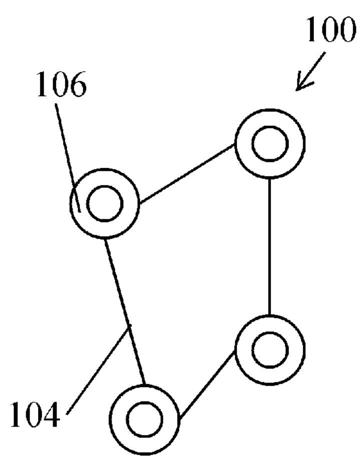
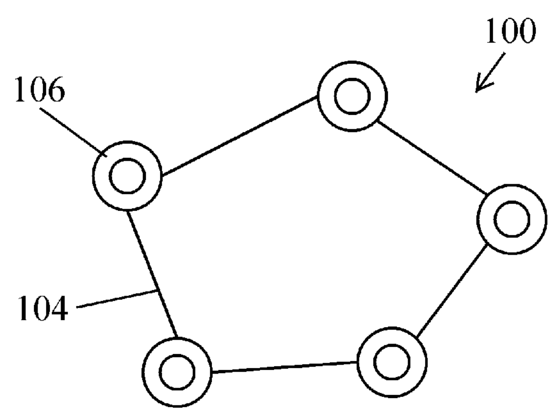


FIGURE 2c



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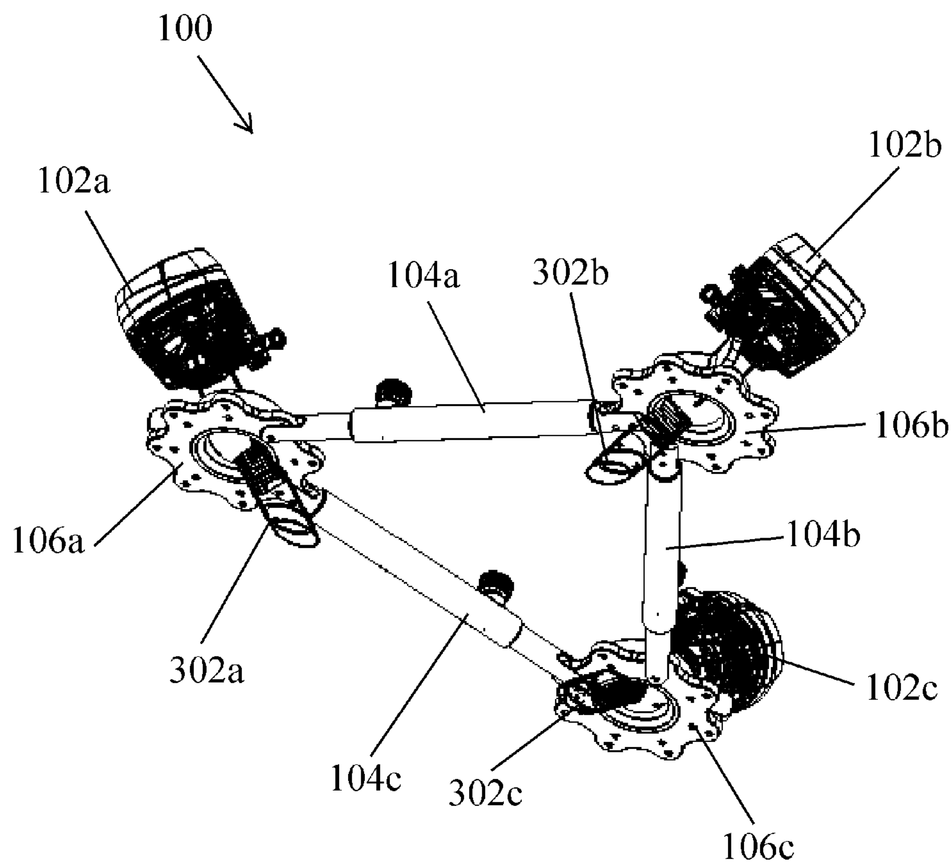
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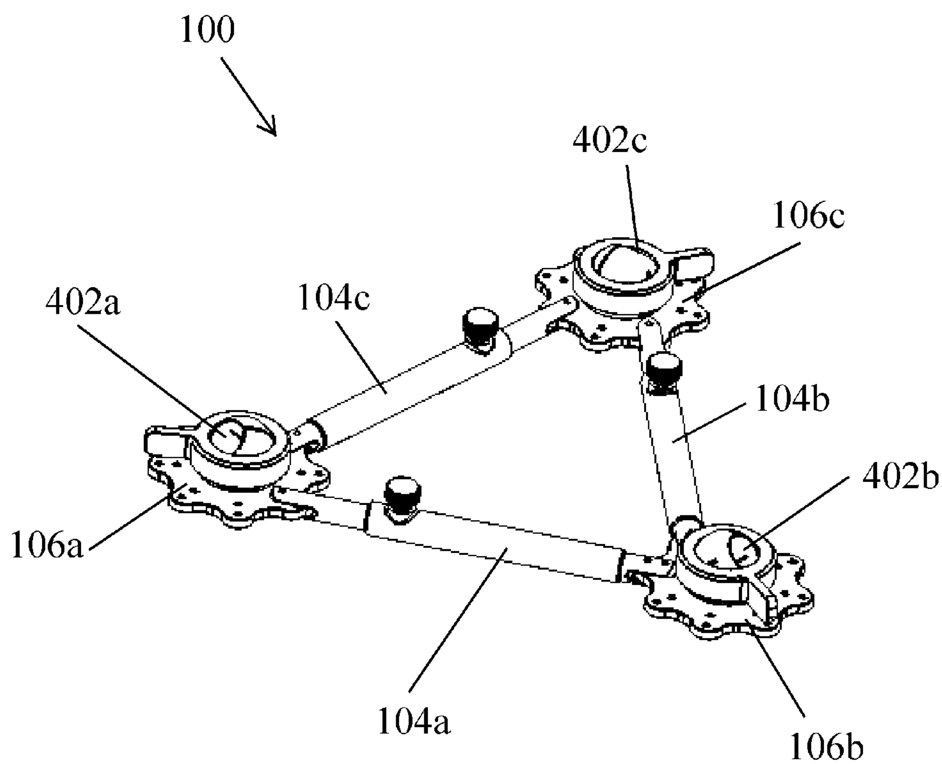
FIGURE 3



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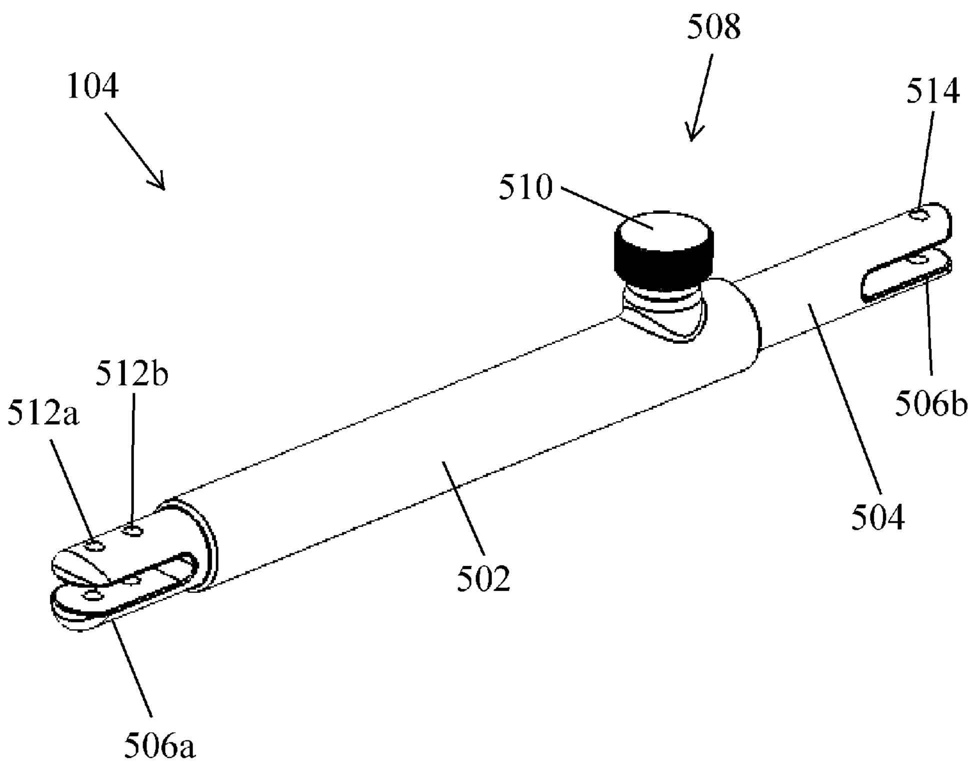

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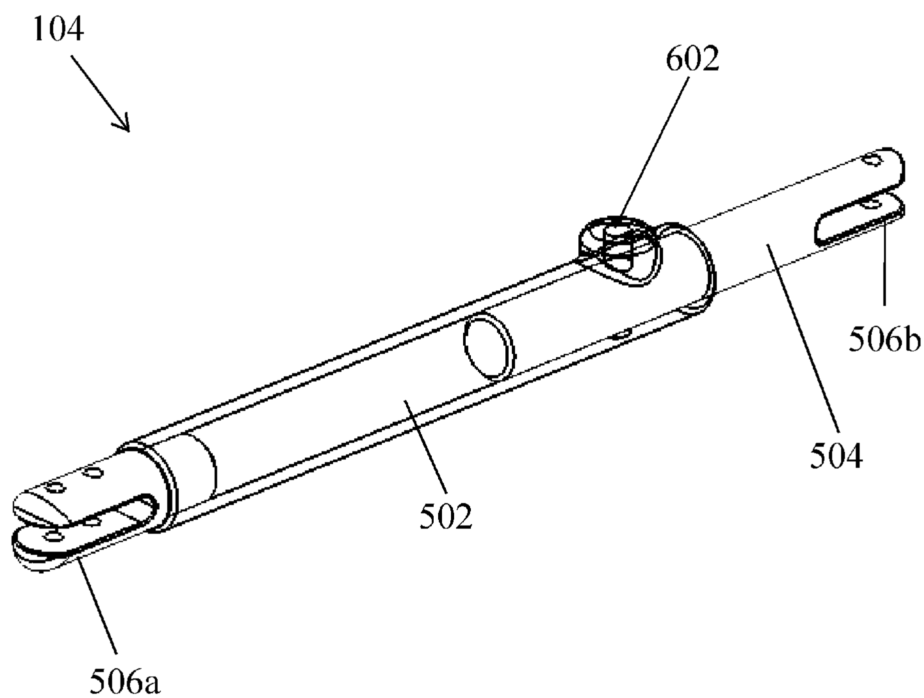

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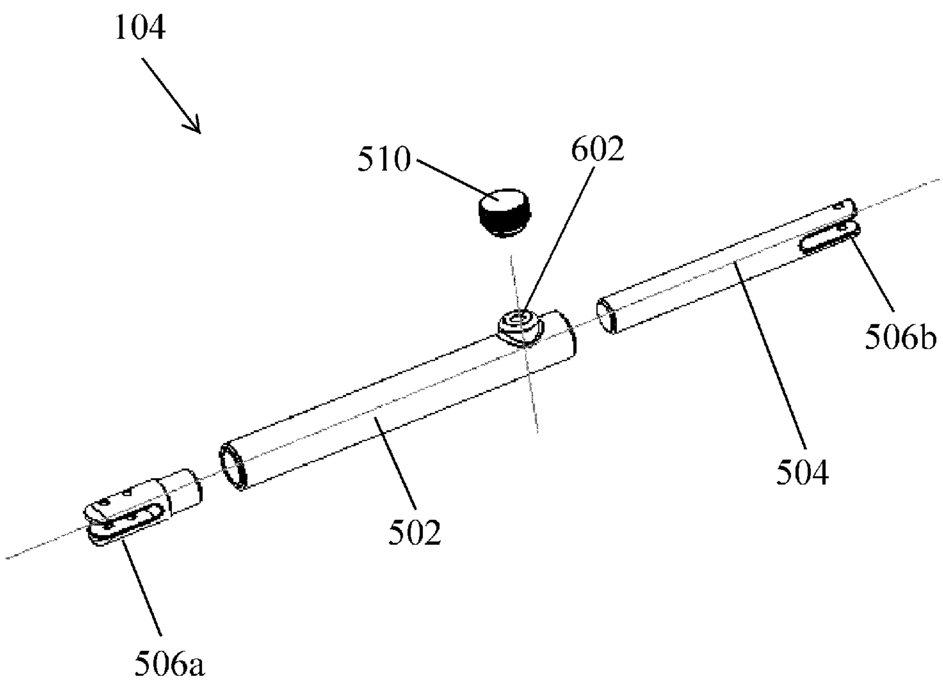

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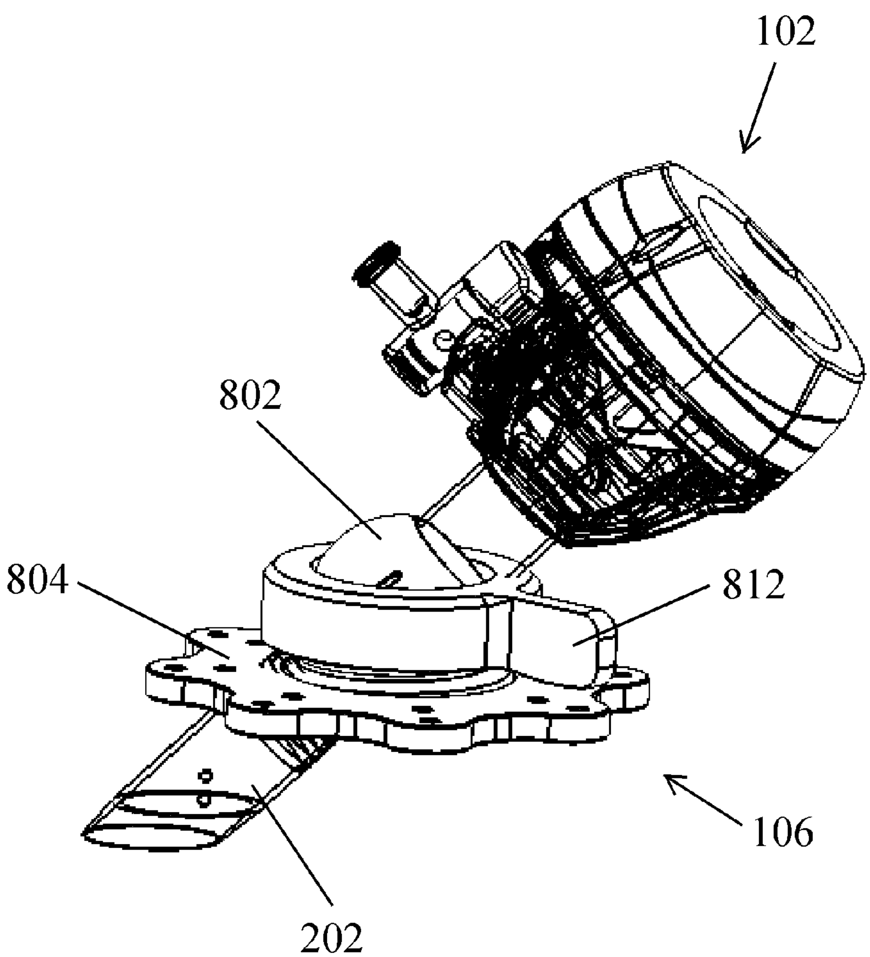

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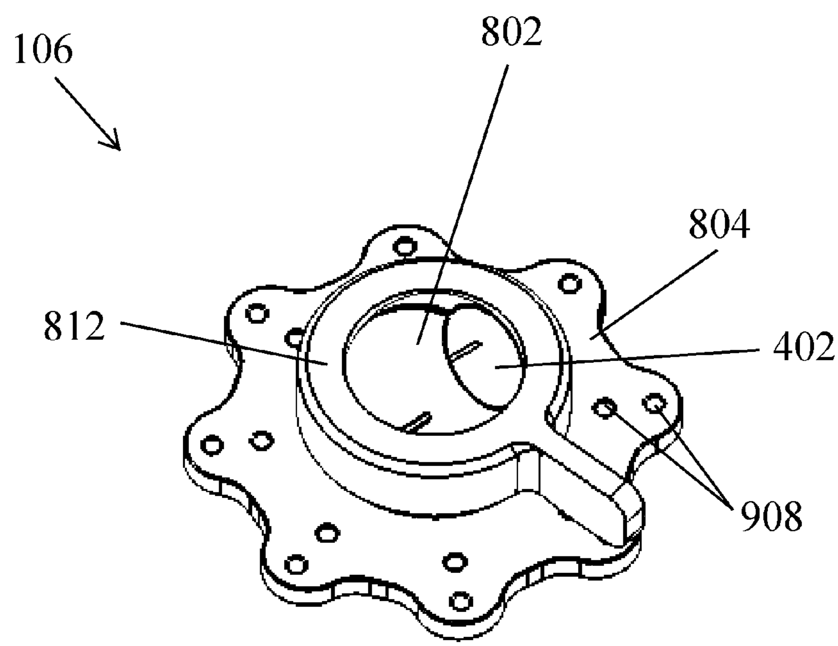

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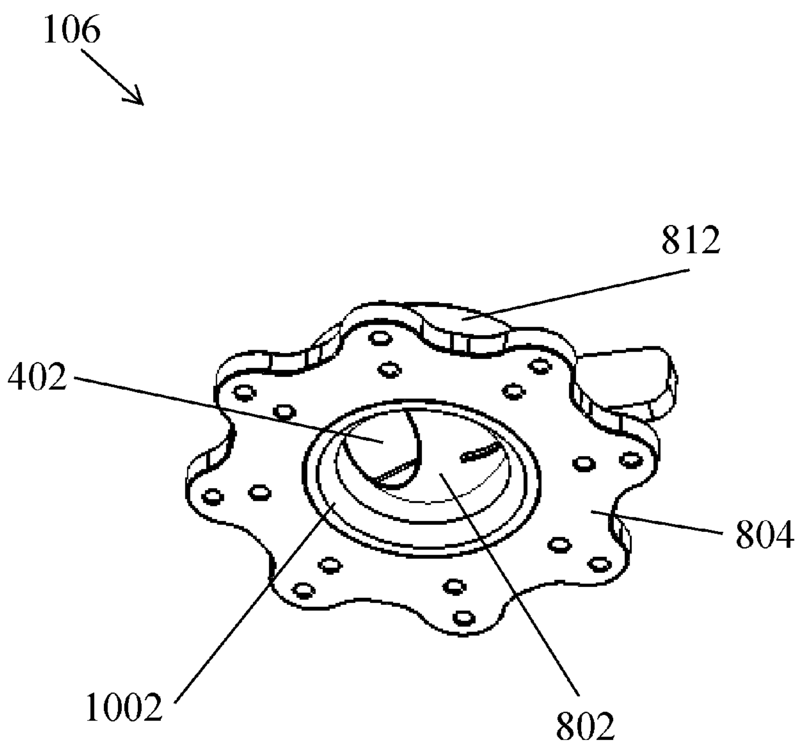

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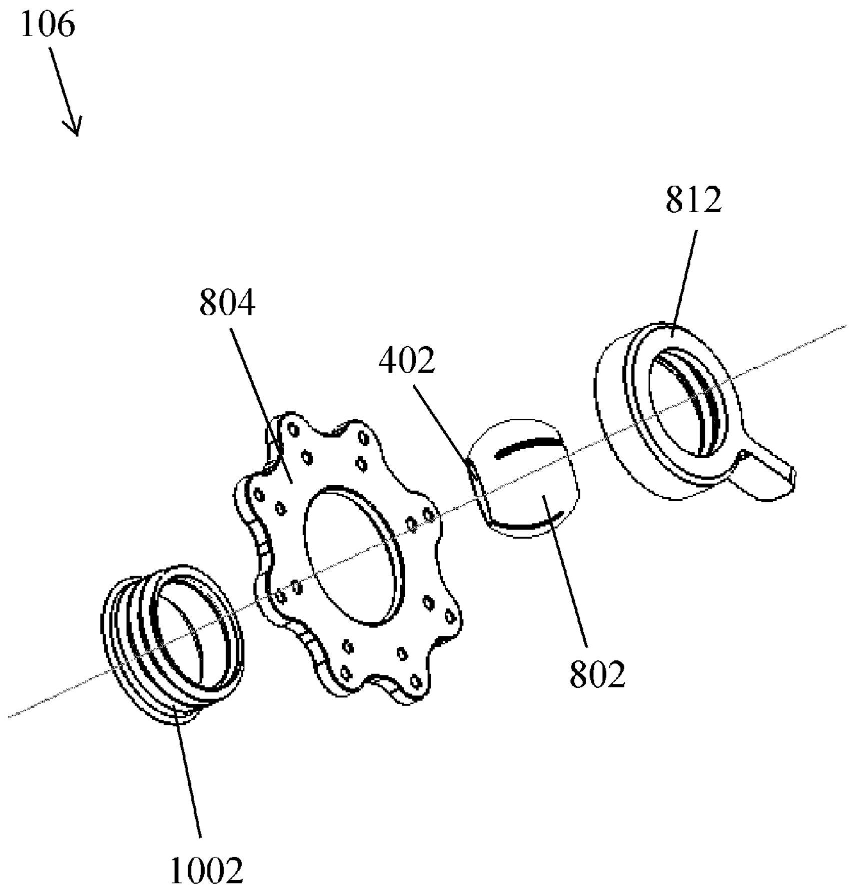

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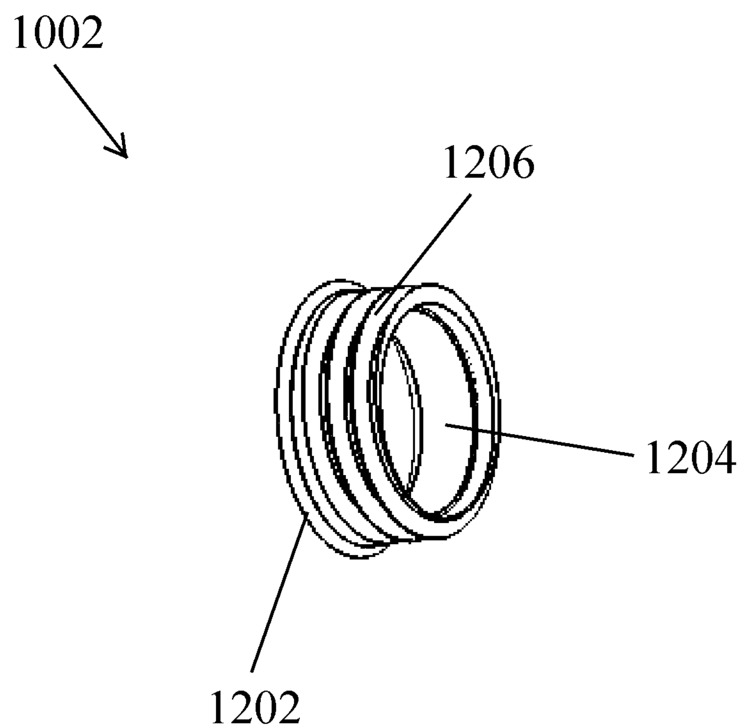

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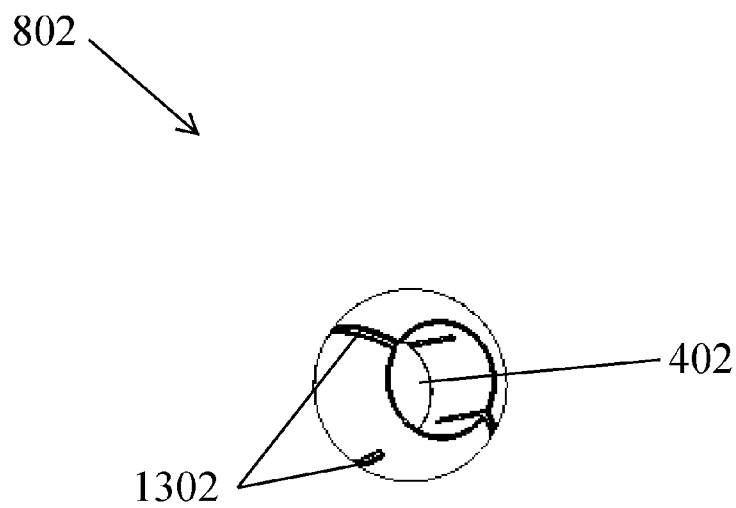

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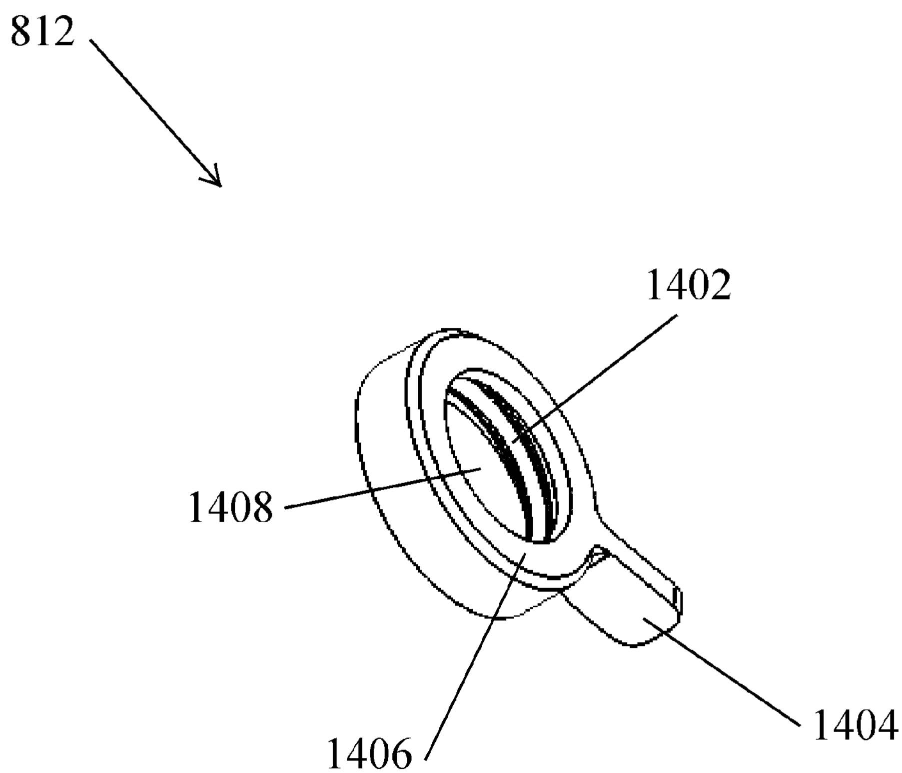

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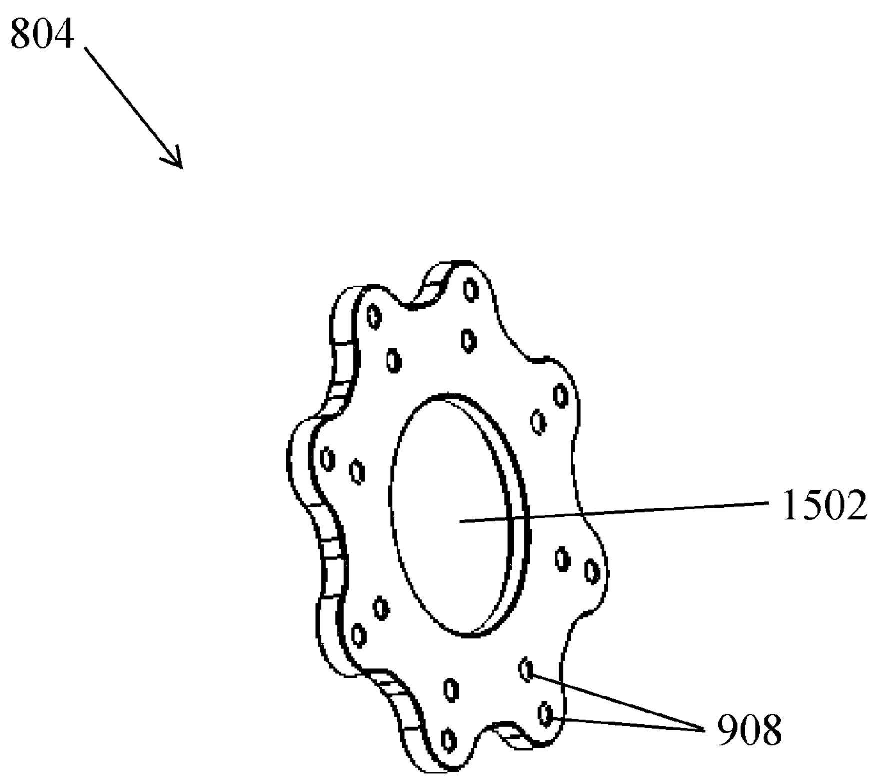

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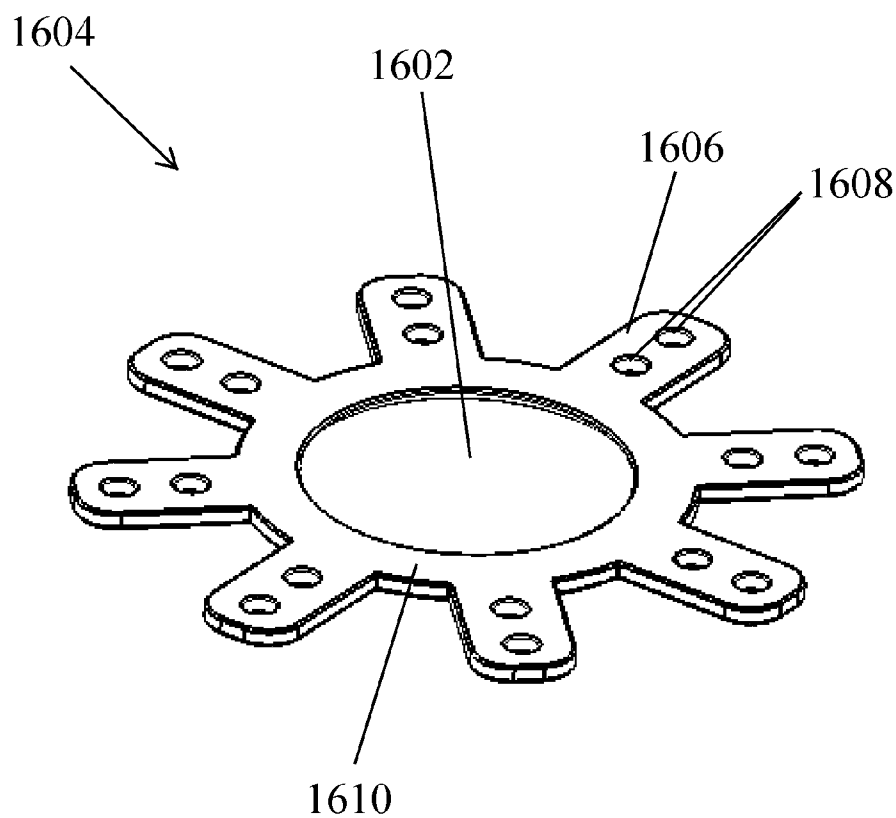

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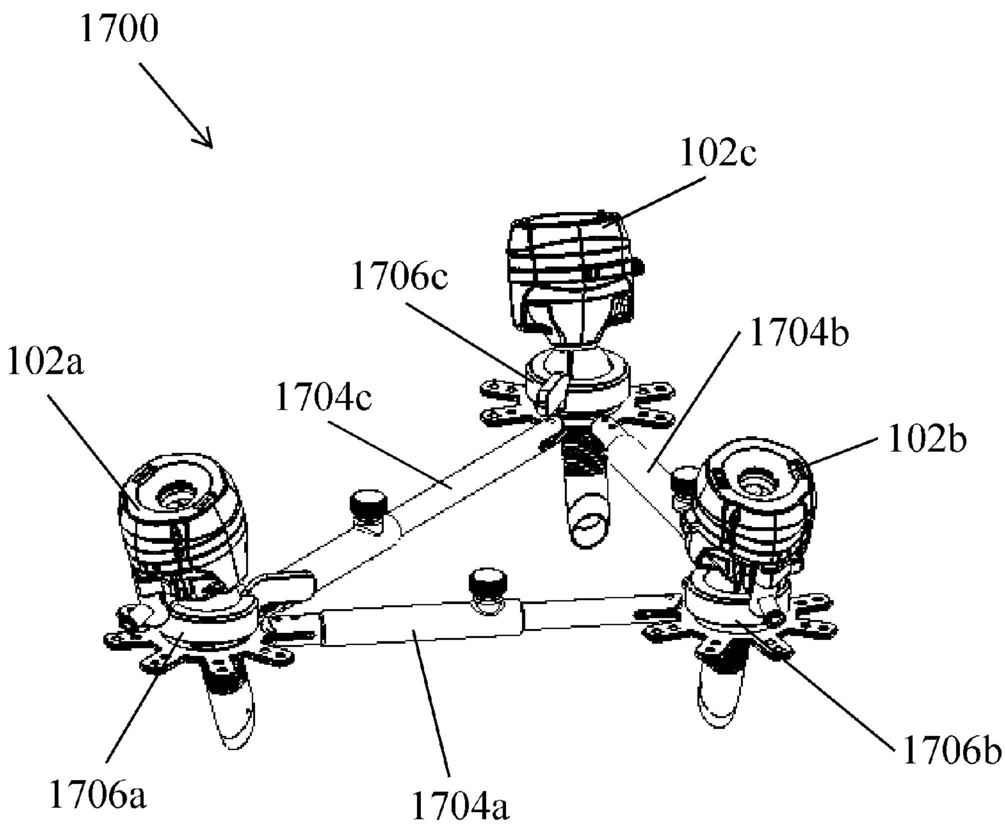

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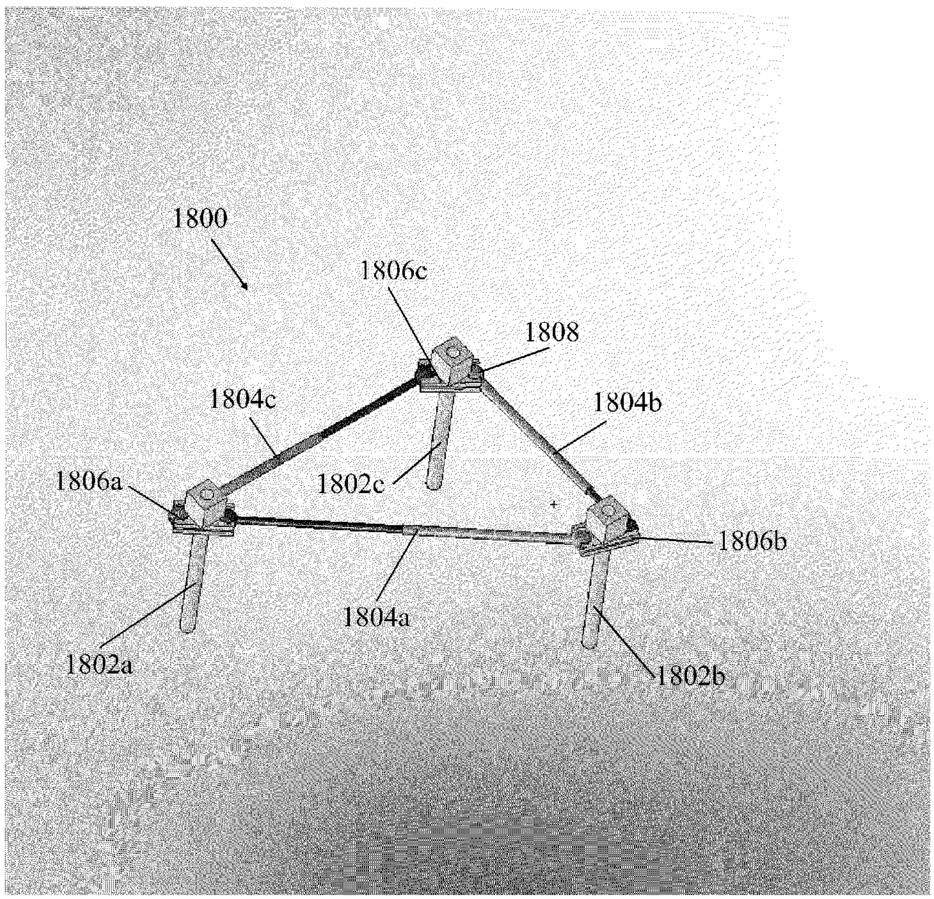
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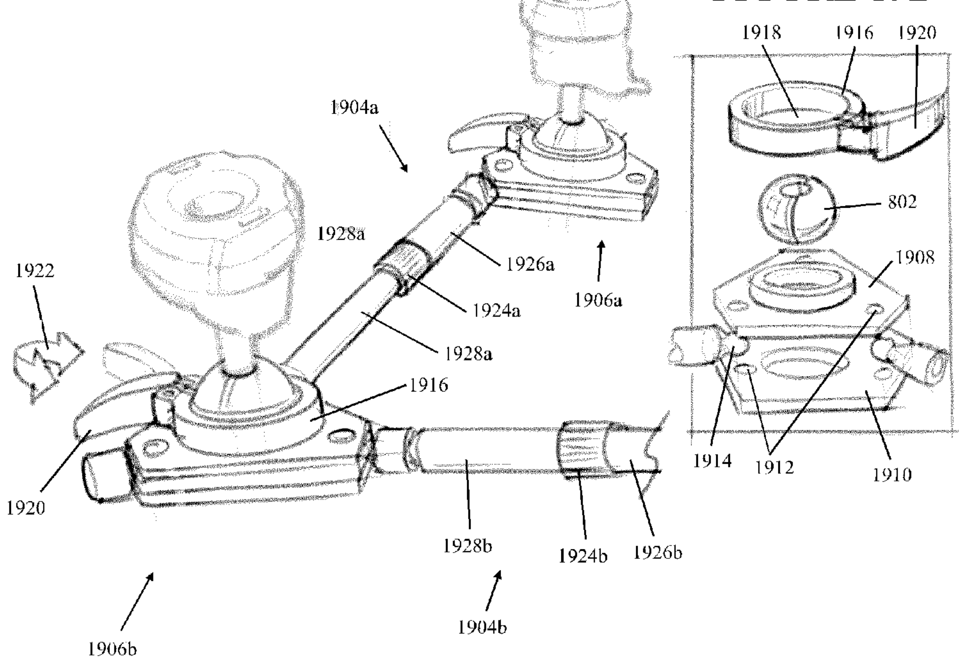
FIGURE 18

FIGURE 19B



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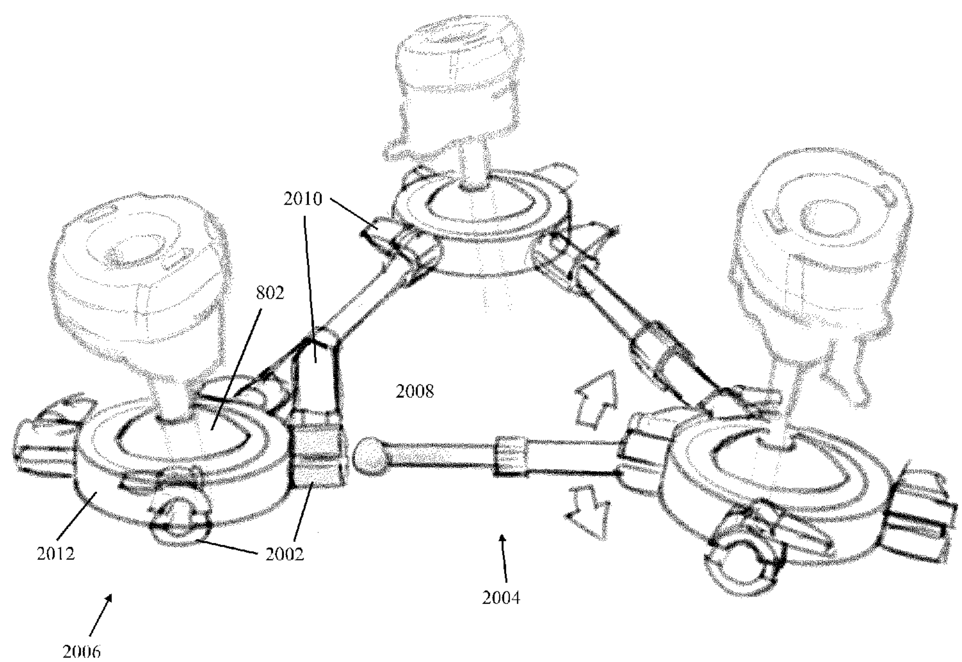

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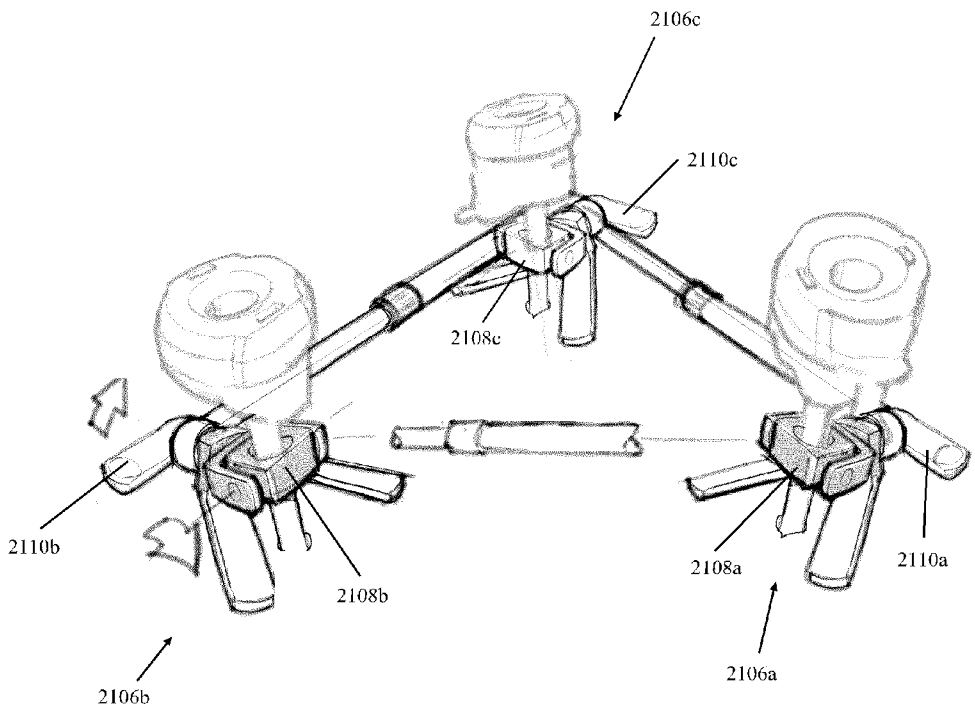

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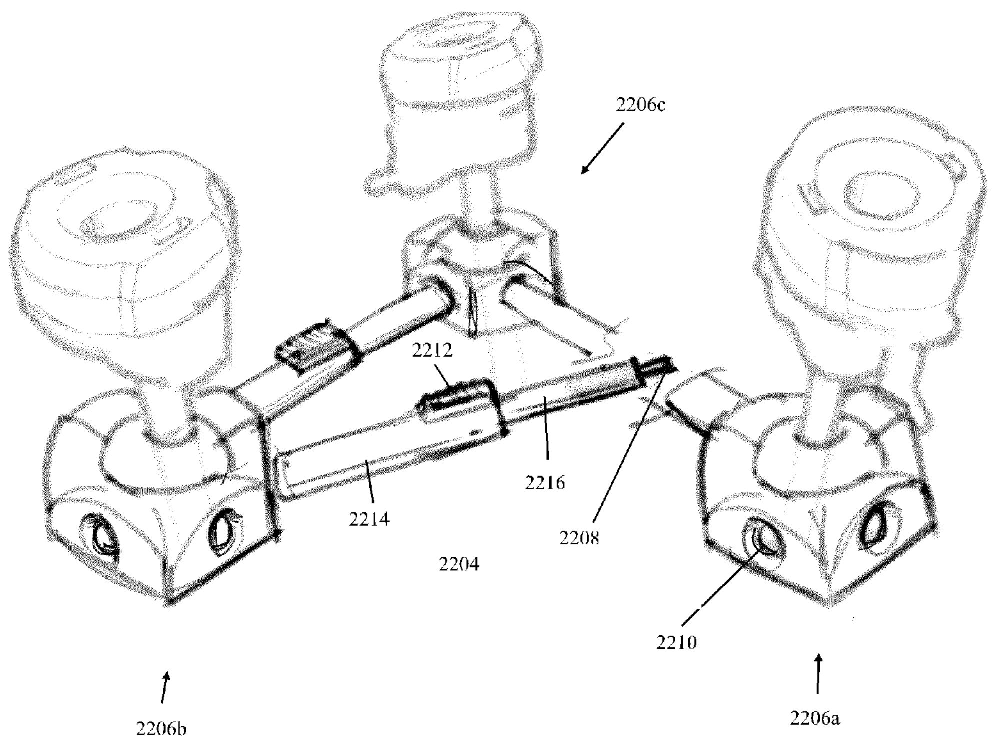
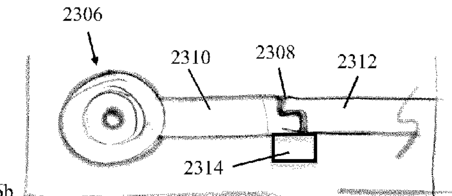


FIGURE 22

FIGURE 23B



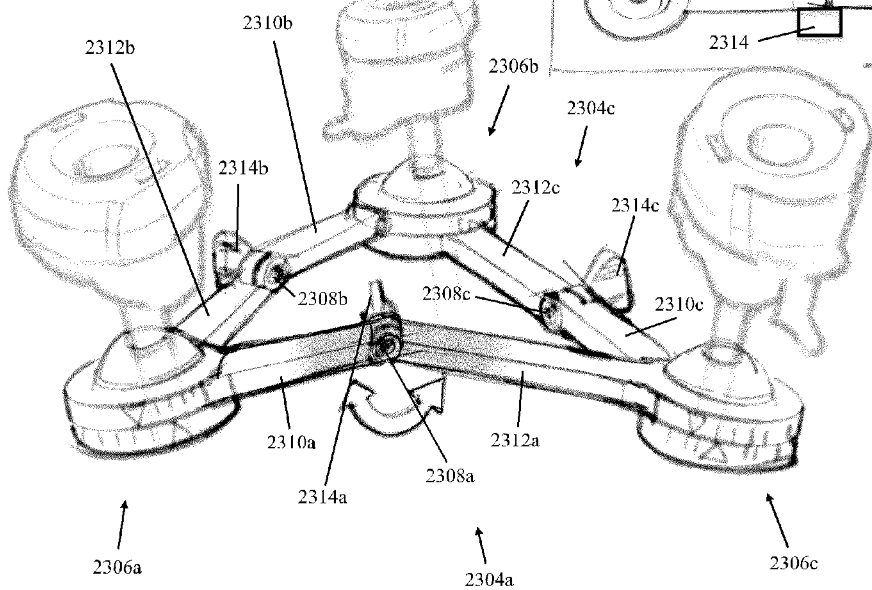
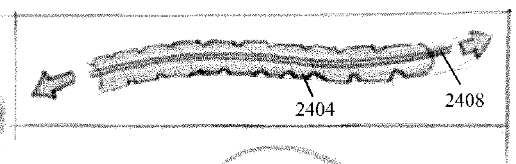


FIGURE 23A

FIGURE 24B



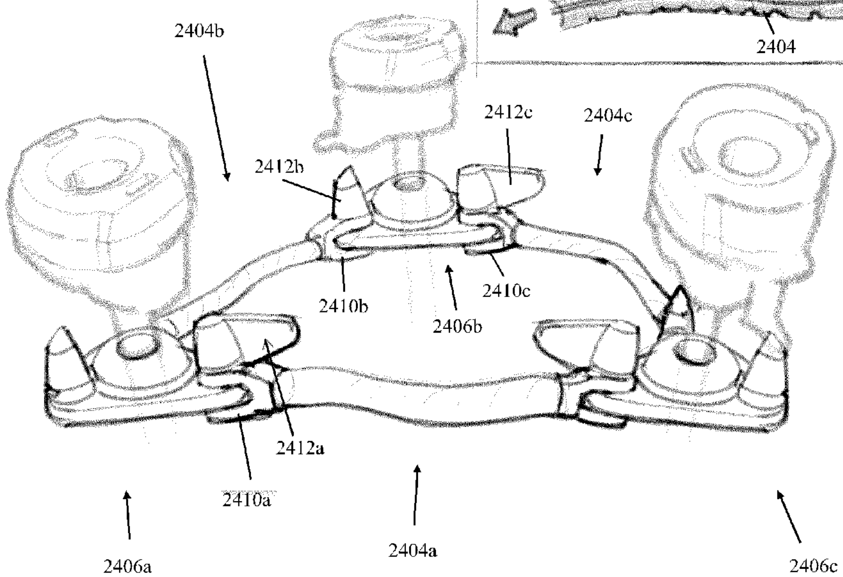


FIGURE 24A

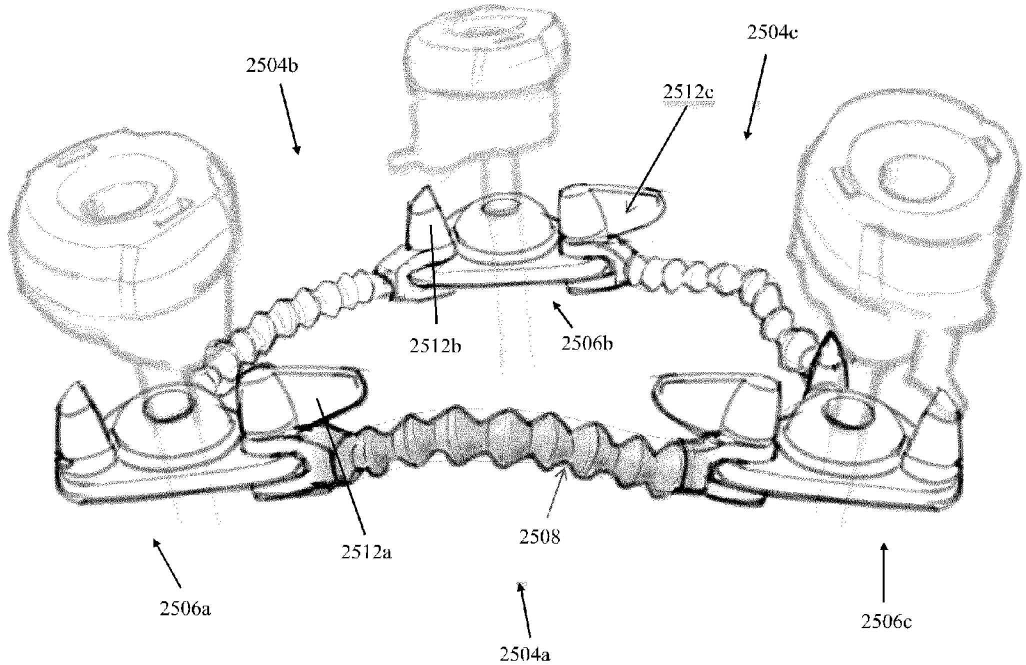


FIGURE 25

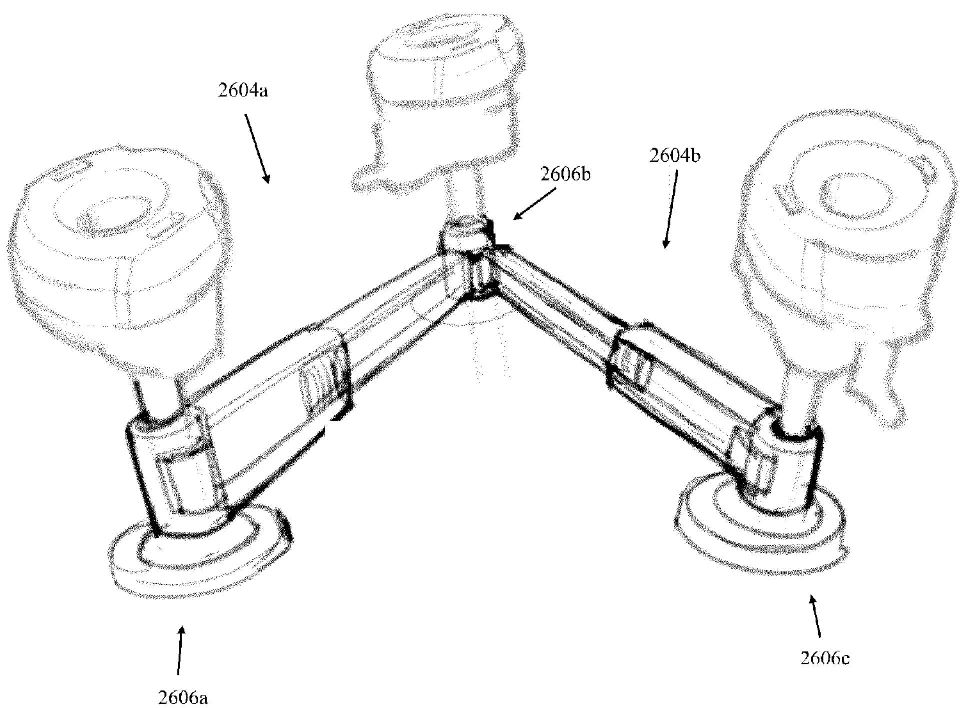
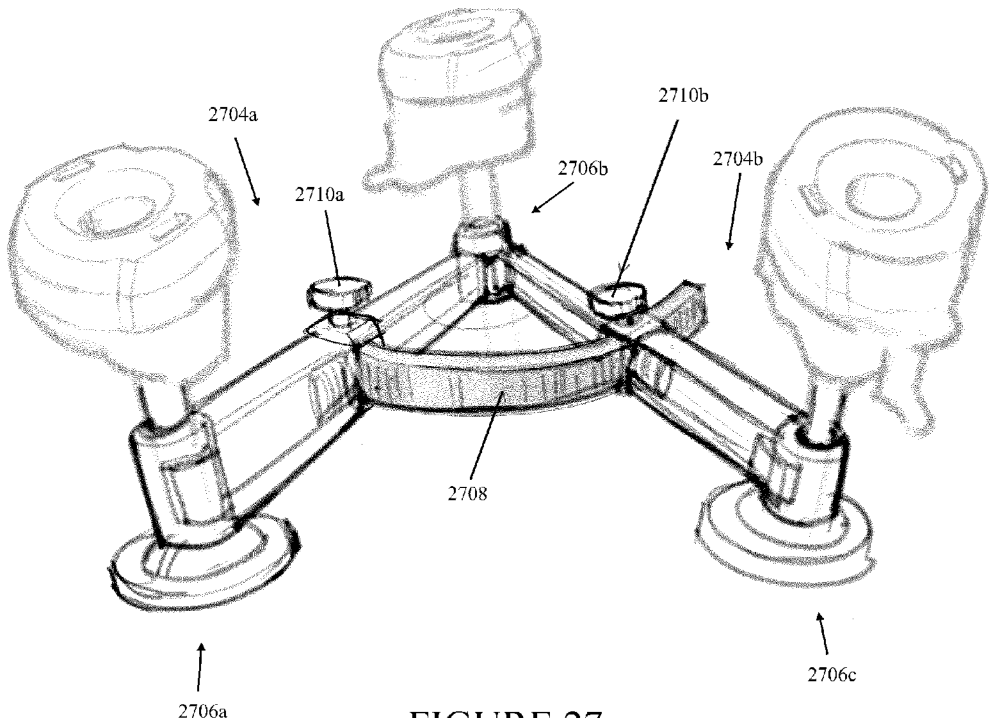


FIGURE 26



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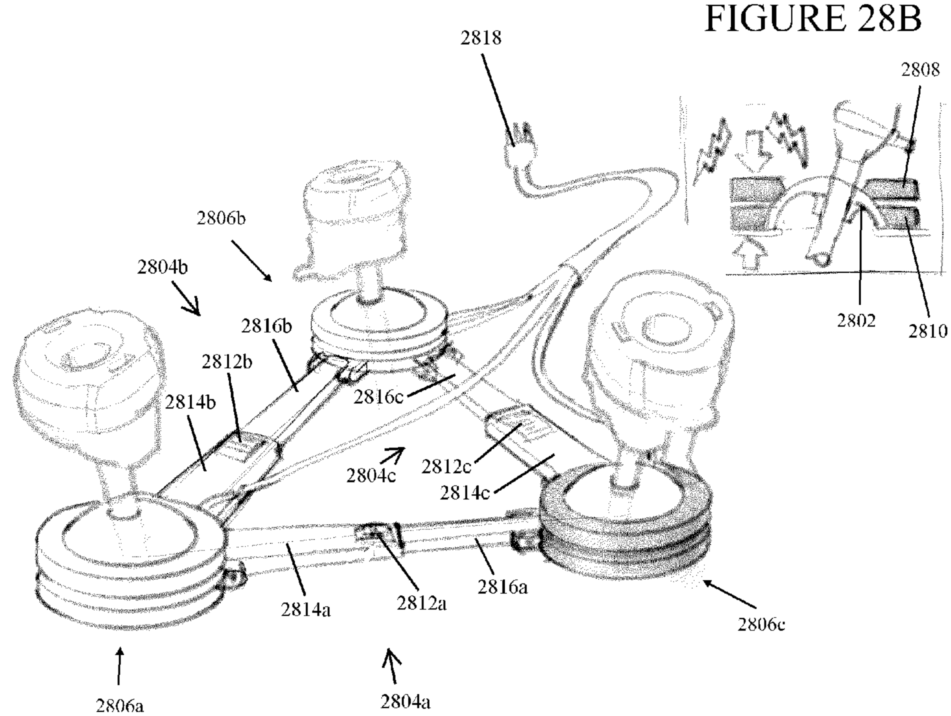
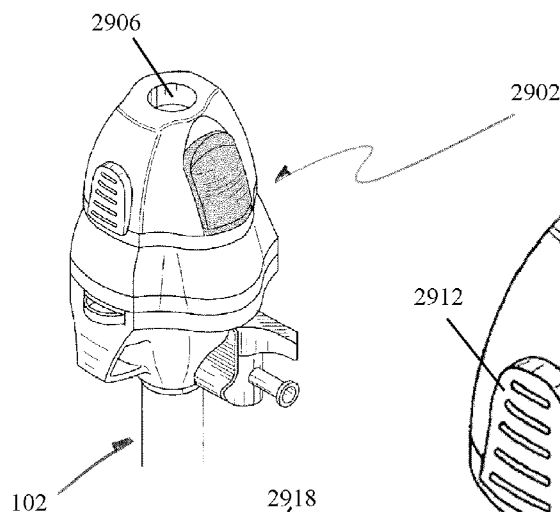
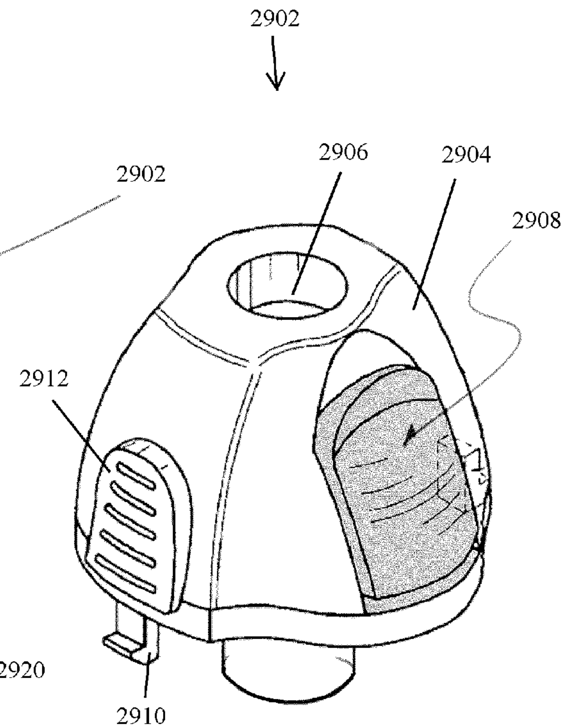


FIGURE 28B

FIGURE 28A

FIGURE 29B





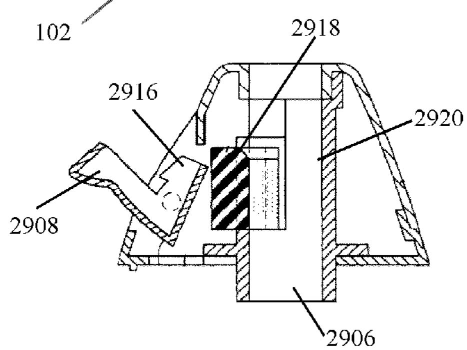


FIGURE 29A

FIGURE 29C

PATIENT-REFERENCED SURGICAL SUPPORT FRAME

FIELD

This invention is related to surgical tools for use in laparoscopic surgery and, in particular, to a patient-referenced surgical support frame and methods for use to orient and retain multiple surgical instruments in a desired position.

BACKGROUND

During laparoscopic surgery, a small incision is formed in the abdomen and a trocar is inserted through the incision to form a pathway that provides access to the abdominal cavity. The trocar is used to introduce various instruments and tools into the abdominal cavity, as well as to provide insufflation to elevate the abdominal wall above the organs.

Many laparoscopic procedures require the use of multiple tools simultaneously or in rapid succession, so oftentimes more than one incision is formed and a trocar is placed through each incision. Each trocar, however, is independent of any other trocar and must be held in position throughout the surgery. Releasing a trocar, or the instrument inserted therethrough, allows the trocar and instrument to fall out of position. As a result, surgeons are limited to controlling no more than two trocars or surgical instruments at any time, and any other trocars or surgical instruments must be removed or held by an additional surgeon or assistant.

Accordingly, there is a need in the art for devices and methods for retaining multiple trocars and surgical instruments in relation to both each other and a patient undergoing surgery.

SUMMARY

The present invention generally provides a patient-referenced surgical support frame and methods of use for retaining multiple trocars and/or surgical instruments in relation to both each other and a patient. The devices and methods of the present invention allow a surgeon to effectively position and control multiple surgical instruments by retaining each instrument in a fixed position and/or orientation when not in use by the surgeon.

In one embodiment, a surgical support frame is provided including at least three support members connected to one another by at least two adjustable linkages. Each support member has a lumen extending therethrough for receiving a cannula (e.g., a cannula at a distal end of a trocar or other surgical access device). Each support member is also configured such that a cannula extending through one of the at least three support members is angularly adjustable relative to a cannula extending through another one of the at least three support members. In addition, a distance between each of the at least three support members is adjustable.

As a result, the surgical support frame can provide polyaxial freedom of movement for one or more cannulas extending therethrough. This can be accomplished in a variety of manners, including, for example, by providing for polyaxial angular adjustment of a support member having a cannula extending therethrough. In other embodiments, the support member can be rigidly or pivotably fixed to the adjustable linkages and can include a mechanism to receive a cannula and provide for polyaxial angular adjustment of the cannula with respect to the support member.

The surgical support frame of the present invention can have any number of modifications or additional features. For example, in some embodiments, the surgical support frame can include at least three adjustable linkages that can be arranged to define a perimeter of an enclosed shape. By way of further example, in some embodiments, the at least three support members can include first, second, and third support members, and the adjustable linkages can be arranged to define a perimeter of a triangle. In other embodiments, the at least three support members can include first, second, third, and fourth support members, and the adjustable linkages can be arranged to define a perimeter of a square (or other quadrilateral, e.g., a rectangle, etc.).

In certain embodiments, the surgical support frame of the present invention can also include a locking mechanism associated with at least one of the at least three support members for locking at least one of the at least three support members such that a cannula extending through one of the at least three support members is retained in a desired angular orientation relative to a cannula extending through another one of the at least three support members.

The support members can be attached to the adjustable linkages in a variety of manners. For example, in some embodiments, the support members and adjustable linkages can be connected using ball-and-socket joints that permit polyaxial adjustment of the support member. In such embodiments, the locking mechanism can be configured to restrain the movement of the ball-and-socket joints to retain the support member (and any cannula extending therethrough) in a particular orientation.

In certain other embodiments, the support members can be fixedly or pivotably (e.g., providing only two-dimensional adjustment) attached to the adjustable linkages and can include a separate mechanism for providing polyaxial angular adjustment of a cannula or trocar extending through the support member. This can be accomplished in a variety of manners including, for example, a ball-and-socket joint in which the ball contains a lumen to receive a cannula or trocar and enable polyaxial adjustment with respect to a socket formed in the support member. In such embodiments, the locking mechanism can be configured to prevent this adjustment and/or translation of the cannula or trocar extending through the support member.

In still other embodiments, the adjustable linkages of the surgical support frame can also include a locking mechanism associated with at least one of the at least two adjustable linkages for locking at least one of the at least two adjustable linkages at a desired length.

In another aspect of the invention, a surgical method is provided including positioning at least three support members on a skin surface of a patient where the at least three support member are connected to one another by a plurality of adjustable linkages. The method further includes moving one of the at least three support members to adjust an effective length of at least one of the plurality of adjustable linkages connected thereto. The method also includes angularly orienting a cannula extending through one of the at least three support members to pivot at least a portion of the support member relative to at least one of the plurality of adjustable linkages connected thereto.

In some embodiments, a cannula can be mounted in each support member such that a distal end of each cannula extends through the skin surface and into a body cavity of the patient.

In certain other embodiments, the method can further include inserting an instrument through the cannula and locking the support member in a fixed position such that the support member retains the cannula and the instrument inserted therethrough in a fixed position.

In certain other embodiments, the method can also include locking at least one of the adjustable linkages at a desired length.

In another aspect of the invention, a surgical method is provided including manipulating a first surgical instrument extending through a first cannula mounted on a support frame resting on a skin surface of a patient to position a distal end of the first surgical instrument at a desired location within a body cavity of the patient. The method can also include manipulating a second surgical instrument extending through a second cannula mounted on the support frame to position a distal end of the second surgical instrument at a desired location with a body cavity of the patient. Still further, the method can include locking at least one of the first and second cannulas in a fixed orientation relative to the support frame such that the distal end of at least one of the first and second surgical instruments is maintained in a desired fixed position, and manipulating a third surgical instrument extending through a third cannula mounted on the support frame to position a distal end of the third surgical instrument at a desired location within a body cavity of the patient.

In some embodiments, the support frame can include a plurality of adjustable linkages connecting the first, second, and third cannulas, and manipulating at least one of the first, second, and third surgical instruments can cause at least one of the plurality of adjustable linkages to move such that a distance between any two of the cannulas is adjusted.

In some other embodiments, manipulating the third surgical instrument can be done with at least one of the first and second cannulas locked in a fixed orientation.

Still further, in certain embodiments, the method can include manipulating a fourth surgical instrument extending through a fourth cannula mounted on the support frame to position a distal end of the fourth surgical instrument at a desired location within a body cavity of the patient.

Using the teachings of the present invention, surgeons involved in laparoscopic procedures can more quickly and efficiently control and position multiple surgical instruments extending into a body cavity of a patient at multiple locations. The surgical support frame of the present invention is able to aid the surgeon by providing a frame of reference for each surgical instrument fixed to the patient and related to each other instrument in use. As a result, the frame can maintain each instrument in a fixed position and/or orientation with respect to both the patient and each other instrument in use.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be more fully understood from the following detailed description taken in conjunction with the accompanying drawings, in which:

FIG. **1** is a top perspective view of one embodiment of a surgical support frame supporting three trocars;

FIG. **2***a* is a top view illustration of one embodiment of a surgical support frame including four support members;

FIG. **2***b* is a top view illustration of an alternative embodiment of a surgical support frame including four support members;

FIG. **2***c* is a top view illustration of another embodiment of a surgical support frame including four support members;

FIG. **2***d* is a top view illustration of one embodiment of a surgical support frame including five support members.

FIG. **3** is a bottom perspective view of the surgical support frame of FIG. **1**;

FIG. **4** is a top perspective view of the surgical support frame of FIG. **1**, shown without any trocars;

FIG. **5** is a perspective view of one of the adjustable linkages of the surgical support frame of FIG. **1**;

FIG. **6** is a transparent view of the adjustable linkage of FIG. **5**;

FIG. **7** is an exploded view of the adjustable linkage of FIG. **5**;

FIG. **8** is a perspective view of one embodiment of a support member of the surgical support frame of FIG. **1**, shown retaining a trocar;

FIG. **9** is a top perspective view of the support member of FIG. **8** shown without a trocar;

FIG. **10** is a bottom perspective view of the support member of FIG. **9**;

FIG. **11** is an exploded view of the support member of FIG. **9**;

FIG. **12** is a perspective view of a receiving member of the support member of FIG. **9**;

FIG. **13** is a perspective view of a receiving ball of the support member of FIG. **9**;

FIG. **14** is a perspective view of one embodiment of a locking mechanism of the support member of FIG. **9**;

FIG. **15** is a perspective view of one embodiment of a linkage plate of the support member of FIG. **9**;

FIG. **16** is a perspective view of an alternative embodiment of a support member linkage plate of the present invention;

FIG. **17** is a perspective view of another embodiment of a surgical support frame of the present invention;

FIG. **18** is a perspective view of yet another embodiment of a surgical support frame of the present invention;

FIG. **19**A is a perspective view of another embodiment of a surgical support frame including a collet locking mechanism;

FIG. **19**B is an exploded view of the support member assembly of FIG. **19**A;

FIG. **20** is a perspective view of another embodiment of a surgical support frame including ball-and-socket linkage attachments;

FIG. **21** is a perspective view of another embodiment of a surgical support frame including universal joint support members;

FIG. **22** is a perspective view of another embodiment of a surgical support frame including magnetic linkage attachments;

FIG. **23**A is a perspective view of another embodiment of a surgical support frame including pivoting linkages;

FIG. **23**B is a top view of an adjustable linkage of the surgical support frame in FIG. **23**A;

FIG. **24**A is a perspective view of another embodiment of a surgical support frame including flexible adjustable linkages;

FIG. **24**B is a side view of an adjustable linkage of the surgical support frame in FIG. **24**A;

FIG. **25** is a perspective view of another embodiment of a surgical support frame including flexible adjustable linkages;

FIG. **26** is a perspective view of another embodiment of a surgical support frame including two rigid telescoping adjustable linkages;

FIG. **27** is a perspective view of another embodiment of a surgical support frame including two telescoping linkages coupled to one another by a spread tie bar;

FIG. **28**A is a perspective view of another embodiment of a surgical support frame including an electromagnetic locking mechanism;

FIG. **28**B is a cross-sectional view of a support member of the surgical support frame of FIG. **28**A; and

FIG. **29**A is a perspective view of an instrument locking member of the present invention;

FIG. **29**B is a perspective view of the instrument locking member in FIG. **29**A disposed on the proximal end of a trocar; and

FIG. **29**C is a cross-sectional view of the instrument locking member in FIG. **29**A.

DETAILED DESCRIPTION

Certain exemplary embodiments will now be described to provide an overall understanding of the principles of the devices and methods disclosed herein. One or more examples of these embodiments are illustrated in the accompanying drawings. Those skilled in the art will understand that the devices and methods specifically described herein and illustrated in the accompanying drawings are non-limiting exemplary embodiments and that the scope of the present invention is defined solely by the claims. The features illustrated or described in connection with one exemplary embodiment may be combined with the features of other embodiments. Such modifications and variations are intended to be included within the scope of the present invention.

In one aspect of the invention, a surgical support frame is provided that can be used during a laparoscopic procedure to retain one or more surgical instruments in a particular position and/or orientation with respect to a patient. One embodiment of a surgical support frame of the present invention is illustrated in FIG. **1**. As shown, the surgical support frame **100** can be configured to hold one or more cannulas (e.g., cannulas of trocars **102**) in a particular orientation with respect to the other cannula(s) and with respect to the patient.

The frame **100** can be configured to be placed on a skin surface of a patient. For example, the surgical support frame **100** can be placed on top of a patient's torso when the patient is lying supine on a gurney. As a result, the frame is not only able to hold each cannula in a desired position and/or orientation with respect to any other cannula, but also with respect to the body of the patient.

Referring to FIG. **1**, the surgical support frame includes three adjustable linkages **104***a*, **104***b*, **104***c* and three support members **106***a*, **106***b*, **106***c*. Two or more support members are preferred to ensure that the surgical support frame rests on the body of a patient in a stable position. Each support member **106***a-c* can be movably connected to the other support members by one or more of the plurality of adjustable linkages **104***a-c*. As shown, the first support member **106***a* is connected to the second support member **106***b* by the first adjustable linkage **104***a*, the second support member **106***b* is connected to the third support member **106***c* by the second adjustable linkage **104***b*, and the third support member **106***c* is connected to the first support member **106***a* by the third adjustable linkage **104***c*. As a result of these connections, the surgical support frame **100** defines an enclosed shape, e.g., a triangle in the illustrated embodiment. Moreover, the connections allow both the angular relation and the distance between each of the support members to be adjusted.

By way of example, FIGS. **2***a-d* illustrate the surgical support frame **100** having additional support members and linkages arranged to define various enclosed shapes. For example, the surgical support frame **100** of FIG. **2***a* is arranged to form a square (i.e., each adjustable linkage **104** has the same length and the angle between each adjustable linkage connected to a support member **106** is 90 degrees). Each adjustable linkage **104** can, however, be adjusted in length, as shown by double arrows **202**. In FIG. **2***b*, the adjustable linkages **104** are not equal in length and the surgical support frame **100** forms a rectangular shape. In addition to changing length, the angular orientation of the adjustable linkages **104** can also be adjusted, as shown in FIG. **2***c*. Moreover, FIG. **2***d* illustrates an embodiment of a surgical support frame **100** having five support members **106** and five adjustable linkages **104**. One skilled in the art will appreciate that the surgical support frame can be created using any number of support members and adjustable linkages, and that the number of support members and adjustable linkages need not be identical (e.g., an adjustable linkage can be added as a diagonal cross-member to the surgical support frame of FIG. **2***b*, resulting in some support members being connected to more than two adjustable linkages).

Still further, the surgical support frame **100** can provide for polyaxial angular adjustment of a cannula extending through a support member **106***a-c*. FIG. **1** illustrates the various degrees of freedom provided by the surgical support frame **100**. For example, and as described above, the angular orientation between the adjustable linkages **104***a-c* can be adjusted as shown by angular adjustment indicators **108***a*, **108***b*, **108***c*. Each support member **106***a-c* can also include features to allow angular adjustment of a cannula extending therethrough about a central axis **110***a*, **110***b*, **110***c* of the support member **106***a-c*. In addition, each cannula **102***a*, **102***b*, **102***c* extending through a support member **106***a-c* can translate along its own axis through the support member **106***a-c*. Accordingly, the surgical support frame **100** provides polyaxial angular adjustment of cannulas **102***a-c* in relation to each other, the support frame, and the patient.

FIGS. **3** and **4** show alternate views of the surgical support frame **100** shown in FIG. **1**. As shown in FIG. **3**, each support member **106***a-c* has a lumen extending therethrough for receiving a cannula, such as a trocar cannula **302***a*, **302***b*, **302***c* on the distal end of a trocars **102***a-c*. A person skilled in the art will appreciate that a variety of trocars and other surgical access devices can be used with the surgical support frame of the present invention. An exemplary trocar is disclosed in U.S. Pat. No. 7,918,826 to Armstrong et al. entitled "Trocar Assembly," the teachings of which are hereby incorporated by reference in its entirety. The lumen **402***a*, **402***b*, **402***c* that each trocar **102***a-c* extends through is shown in more detail in FIG. **4**, which illustrates the surgical support frame **100** without any trocars **102***a-c*.

As mentioned above, each surgical support frame can include a plurality of adjustable linkages **104***a-c*. FIGS. **5-7** illustrate one exemplary embodiment of an adjustable linkage (linkage **104** is shown to represent linkages **104***a-c*) of the present invention. As shown in FIG. **5**, the adjustable linkage **104** has a telescoping rod assembly that includes a male rod section **504** that is slidably received within a lumen of a female rod section **502**. Each rod section can include terminal ends **506***a*, **506***b*. The terminal ends **506***a*, **506***b* can have a variety of configurations to facilitate mating with the support members **106***a-c*. For example, the terminal end **506***a* can be a separate component mated to the female rod section **502**, and the terminal end **506***b* can be formed as an integral part of the male rod section **504**. Any combination of these integrated or modular end components can be used with either terminal end and such modifications are considered within the scope of the invention. In addition, any number of various mating shapes may be used for terminal ends **506***a*, **506***b*. For example, the terminal ends **506***a*, **506***b* can be jaw members as illustrated in FIG. **5**, or can be ball-shaped features that are received in a complementary socket feature, as discussed below with respect to FIG. **18**. Furthermore, the terminal ends **506***a*, **506***b* can be configured to mate to a support member in any of a fixed orientation (as shown by terminal end **506***a* having dual bores **512***a*, **512***b* to receive attachment pins or bolts) or an adjustable or pivotable orientation (as shown by terminal end **506***b* having a single bore **514** to receive a single attachment pin or bolt).

The adjustable linkage **104** can also include a locking mechanism **508** configured to lock the adjustable linkage at a desired length. The locking mechanism **508** can be implemented in a variety of manners known in the art. For example, the locking mechanism **508** can include a thumbscrew **510** extending through a threaded hole **602** formed in the female rod section **502**, as shown in FIGS. **5-7**. The distal end of thumbscrew **510** can press against the male rod section **504** to prevent the male rod section **504** from moving with respect to the female rod section **502**. In other embodiments, the locking mechanism **508** can be implemented using electrically or pneumatically actuated components. Such embodiments can allow the simultaneous locking and unlocking of multiple adjustable linkages **104**. These variations are all considered to be within the scope of the present invention.

FIGS. **8-11** illustrate one exemplary embodiment of a support member (support member **106** is shown to represent supports **106***a-c*) of the present invention. As shown in FIG. **8**, support member **106** can be configured to retain a trocar **102** in a desired orientation and/or position by receiving the distal trocar cannula (trocar cannula **202** is shown to represent cannulas **202***a-c*) through the support member **106**. FIG. **9** illustrates the support member **106** without a trocar **102**. While the support member **106** can have a variety of configurations, in an exemplary embodiment the support member **106** is in the form of a body having an opening therethrough for receiving a portion of an access device, such as a trocar cannula **102**. The shape of the body can vary. By way of non-limiting example, in the illustrated embodiment the support member **106** has a generally circular shape with a substantially planar distal surface to allow positioning on a skin surface. As best shown in FIG. **11**, the illustrated support member **106** generally includes a receiving member **1002**, a receiving ball **802** polyaxially disposed within the receiving member **1002**, and a cap **812** for retaining the ball **802** within the receiving member **1002**. The ball **802** can have a lumen **402** extending therethrough for receiving the cannula. The support member **106** can also have a linking plate **804** disposed around the receiving member **1002** for mating with one or more of the telescoping linkages **104***a-c*. As a result of the receiving ball **802** being polyaxially disposed in the receiving member **1002**, any cannula (e.g., trocar cannula **202**) inserted through the receiving ball **802** will also be capable of moving polyaxially with respect to the receiving member **1002** and other components of the surgical support frame **100**.

As shown in FIG. **12**, the receiving member **1002** can form the base of the support member **106**. The receiving member **1002** can have a substantially cylindrical shape with a flange **1202** formed on a terminal end thereof and configured to abut against a central lumen **1502** of the support member linkage plate **804** (shown in FIG. **15**). The receiving member **1002** can define an inner lumen **1204** configured to house the receiving ball **802** without allowing the receiving ball to pass through the central lumen (e.g., the diameter of the inner lumen **1204** is smaller than the diameter of the receiving ball **802**). The receiving member **1002** can also include threads **1206** formed on its outer surface and configured to interface with complementary threads **1402** formed on the inner surface of locking mechanism cap **812** (shown in FIG. **14**).

The receiving ball **802**, shown in isolation in FIG. **13**, can have a generally spherical shape with a lumen **402** formed therethrough for receiving a trocar cannula **202**. In addition, the receiving ball **802** can include one or more compression slots **1302** to allow the lumen **402** to adjust in diameter in response to actuation of the locking mechanism (e.g., locking mechanism cap **812**). For example, compression slots **1302** that are generally coaxial to the lumen **402** can allow the receiving ball **802** (and lumen **402**) to compress in response to pressure exerted on the ball by the locking mechanism. As the size of the lumen **402** decreases, a trocar cannula extending therethrough can be engaged by the ball **802** and fixed in a desired position such that it cannot rotate with respect to the support member **106** or translate through the lumen **402** formed in the support member.

The support member **106** can also include a locking mechanism configured to retain the receiving ball **802** within the receiving member **1002** and to selectively restrain movement of the ball **802** relative to the receiving member **1002**, thereby restraining the movement of any trocar cannula **202** disposed in the lumen **402** of the receiving ball **802**. FIG. **14** illustrates one embodiment of a locking mechanism that is in the form of a threaded cap **812**. As shown, the cap **812** can be ring-shaped with inner complementary threads **1402**, a handle **1404** for manual actuation, and a flange **1406** with a central lumen **1408** configured to house the receiving ball **802** without allowing the receiving ball to pass through the central lumen **1408** (e.g., the diameter of the central lumen **1408** is smaller than the compressed diameter of the receiving ball **802**, similar to the inner lumen **1204** of the receiving member **1002** described above). In this embodiment, as the cap **812** is threaded down onto the threads **1206** of the receiving member **1002**, the flange **1406** abuts against the receiving ball **802** and compresses the ball against inner lumen **1204** of the receiving member **1002**. Interference between the receiving ball **802**, cap **812**, and receiving member **1002** restrains the receiving ball—along with any cannula extending therethrough—from moving with respect to the support member. In other embodiments, the locking mechanism can be implemented with electrically or pneumatically actuated components, as will be discussed in detail below with respect to FIGS. **28**A and **28**B.

FIG. **15** illustrates one embodiment of a support member linkage plate **804**. The support member linkage plate **804** can be formed integrally with the receiving member **1002** or, in some embodiments, it can be disposed between the receiving member **1002** and the cap **812** to allow the support member **106** to be coupled to one or more linkages. The modular construction of the support member **106** facilitates easy disassembly for cleaning or replacement of broken components. The linkage plate **804** can have a variety of shapes and sizes to facilitate mating with a terminal end **506** of one or more of the adjustable linkages **104***a-c*. As shown in FIG. **15**, the linkage plate **804** is generally ring-shaped and includes a plurality of attachment points **908** formed therein. The attachment points **908** can be in the form of depressions or other mating features formed on the surface of linkage plate **804**, or can be in the form of bores formed therethrough for receiving an attachment pin or bolt. FIGS. **19-28**, discussed in more detail below, illustrate other additional embodiments of attachment points **908**.

FIGS. **1-15** illustrate one embodiment of a surgical support frame of the present invention. Numerous variations of the illustrated embodiment are possible, all of which are considered to be within the scope of the present invention. For example, FIG. **16** illustrates an alternative embodiment of a support member linkage plate **1604** of the present invention. Linkage plate **1604** includes a central lumen **1602**, similar to central lumen **1502** shown in FIG. **15**. In this embodiment, however, the linkage plate **1604** has a plurality of attachment arms **1606** extending radially outward from a central ring portion **1610**. Each attachment arm **1606** can have one or more attachment points **1608**, similar to the attachment points

908 discussed above. A person skilled in the art will appreciate that a variety of other shapes are conceivable for use in the linkage plate **1604**.

FIG. **17** illustrates another exemplary surgical support frame **1700** having adjustable linkages **1704***a*, **1704***b*, **1704***c* and support members **1706***a*, **1706***b*, **1706***c* that utilize the alternate support member linkage plate **1604** discussed above. Similar to the surgical support frame **100** shown in FIG. **1**, surgical support frame **1700** can be used to support one or more trocars **102***a*, **102***b*, **102***c* in a desired orientation and/or position with respect to the body of a patient and any other trocars inserted through the frame.

FIG. **18** illustrates another embodiment of a surgical support frame of the present invention. As shown, the surgical support frame **1800** is configured to support one or more trocars **1802***a*, **1802***b*, **1802***c* (or other cannulas for use in surgery) via a plurality of adjustable linkages **1804***a*, **1804***b*, **1804***c* and at least three support members **1806***a*, **1806***b*, **1806***c*. In this embodiment, the adjustable linkages **1804***a-c* and the support members **1806***a-c* are connected by ball-and-socket joints **1808**. The ball-and-socket joints **1808** permit polyaxial angular adjustment of the entire support member, thus angularly orienting any cannula **1802***a-c* extending therethrough.

Both the adjustable linkages **1804***a-c* and the support members **1806***a-c* can include locking mechanisms to restrain the adjustment of the surgical support frame. For example, the adjustable linkages **1804***a-c* can include a locking mechanism similar to the locking mechanism **508** shown in FIG. **5** to prevent the adjustment of the length of any particular adjustable linkage **1804**. Similarly, the support members **1806***a-c* can include a locking mechanism configured to restrain the motion of one or more of the ball-and-socket joints **1808**. An exemplary locking mechanism can be implemented using a manually, electrically, or pneumatically actuated component (e.g., a threaded cap as described above) to increase friction between, for example, a ball formed on the terminal end of an adjustable linkage **1804** and a socket formed in a support member **1806**.

FIG. **19**A illustrates another embodiment of a surgical support frame having ball-and-socket joints that connect each adjustable linkage **1904***a*, **1904***b* to each support member **1906***a*, **1906***b*. As shown most clearly in FIG. **19**B, a socket is formed by connecting a top linkage plate **1908** and a bottom linkage plate **1910** having bores **1912** formed therein such that a ball-shaped terminal end **1914** of an adjustable linkage **1904** can be received and sandwiched between the linkage plates. The linkage plates **1908**, **1910** can be secured together using, for example, screws such that a set amount of pressure is applied to the ball-shaped terminal end of a linkage **1904**. Alternatively, the linkage plates **1908**, **1910** can be adjustable, e.g., using a thumbscrew, such that a user can selectively apply pressure to release or secure a ball-shaped terminal end **1914** with respect to the support member linkage plates.

The surgical support frame illustrated in FIGS. **19**A and **19**B also includes alternative embodiments of the support member and adjustable linkage locking mechanisms. As shown in the figures, the support member locking mechanism can be a ring-shaped collet **1916** fixed to one side of a top linkage plate **1908** using, for example, a screw. The collet **1916** can be sized to surround a receiving ball **802** without allowing the ball to pass through a lumen **1918** formed in the collet. The collet **1916** can include a cam lever **1920** that, when activated (e.g., moved as shown by the arrow **1922**), tightens the ring-shaped collet around the receiving ball **802** so as to restrict its movement.

The adjustable linkage locking mechanism shown in FIG. **19**A can include a threaded cap **1924** that receives an end of the female linkage member **1926** opposite a terminal end that is configured to mate to a support member **1906**. The threaded cap **1924** can have a tapered threaded inner bore and the end of the female linkage member **1926** can have compression slots formed therein to allow compression of the female linkage member as the threaded cap is advanced on to the female linkage member. This compression can reduce the inner bore diameter of the female linkage member **1926**, causing interference between the female linkage member **1926** and the male linkage member **1928** and preventing the adjustable linkage from telescoping.

FIG. **20** illustrates another embodiment of a surgical support frame utilizing ball-and-socket joints to link the support members and adjustable linkages. As shown in the figure, individual sockets **2002** can be formed at various locations around a support member **2006**. These sockets **2002** can be configured to receive a ball-shaped terminal end **2008** of an adjustable linkage **2004**. Each socket **2002** can also have an associated locking mechanism **2010** operable to restrict the movement of the ball-shaped terminal end **2008** within the socket. Locking mechanism **2010** can be, for example, a cam lever that, when actuated, compresses two halves of the socket **2002** together to cause interference with the ball-shaped terminal end **2008** and thereby restrict its movement.

FIG. **20** also shows an alternative embodiment of support member **2006** wherein a ring-shaped collet or other locking mechanism is integral with a support member body **2012**. The support member body **2012** is configured to receive ball **802** and selectively restrict its movement when the locking mechanism is actuated.

FIG. **21** illustrates still another embodiment of a support member **2106**. In the illustrated embodiment, each support member **2106***a*, **2106***b*, **2106***c* includes a universal joint **2108***a*, **2108***b*, **2108***c* having a bore formed therethrough to accept a trocar cannula or other surgical device. Each universal joint **2108***a-c* can include a locking mechanism **2110***a*, **2110***b*, **2110***c* to fix the joint in a desired orientation. The locking mechanism **2110***a-c* can be configured to restrict one or more degrees of freedom of the universal joints **2108***a-c*. For example, and as shown in the figure, the locking mechanism **2110***a-c* can be a handle threaded on to a shaft that is also connected to the universal joint **2108***a-c*. As the threaded handle **2110***a-c* is tightened, it can cause interference with the universal joint **2108***a-c*, thereby restricting its ability to move in one or more directions.

In other embodiments, one or more adjustable linkages can be connected to a support member using a magnetic coupling mechanism. As shown in FIG. **22**, an adjustable linkage **2204** can include a magnetic terminal end **2208** configured to be received within a magnetic socket **2210** of a support member **2206***a*. The support members **2206***a*, **2206***b*, **2206***c* can include a plurality of magnet sockets **2210** at various locations to connect with one or more adjustable linkages **2204** in various orientations.

FIG. **22** also illustrates another embodiment of an adjustable linkage locking mechanism configured to lock the adjustable linkage **2204** at a desired length. As shown, the adjustable linkage **2204** can include a sliding tab **2212** configured to slide along the outer surface of the female linkage member **2214**. The sliding tab **2212** can be further configured to cause interference between the female linkage member **2214** and the male linkage member **2216** when moved in one direction, and to provide clearance when moved in an opposing direction.

In certain other embodiments, the adjustable linkages can be configured to provide adjustment other than to telescope in length. For example, FIG. **23**A illustrates an embodiment of a surgical support frame in which the adjustable linkages **2304***a*, **2304***b*, **2304***c* include a first linkage section **2310***a*, **2310***b*, **2310***c* and a second linkage section **2312***a*, **2312***b*, **2312***c* with a pivot joint **2308***a*, **2308***b*, **2308***c* formed therebetween for allowing the first and second linkage sections to be angularly oriented relative to one another. Pivoting the first linkage sections **2310***a-c* with respect to the second linkage sections **2312***a-c* can also allow adjustment of the effective length of the linkages (i.e., the distance between the terminal ends of the linkages and, thus, any support members **2306***a-c* connected thereto). The adjustable linkages **2304***a-c* can include a locking mechanism associated with the joints **2308***a-c* to fix the linkages in a desired angular orientation. The locking mechanism can include a thumbscrew **2314***a*, **2314***b*, **2314***c* threaded through a bore formed in the first and second linkage sections **2310***a-c*, **2312***a-c*. As shown in the top view of FIG. **23**B, the thumbscrew **2314** can be tightened to squeeze the first and second linkage sections **2310**, **2312** together and cause interference, thereby fixing their orientation with respect to each other.

In still other embodiments, an adjustable linkage can be configured to provide even greater freedom of movement. FIGS. **24**A, **24**B, and **25** illustrate surgical support frames in which the adjustable linkages **2404***a*, **2404***b*, **2404***c*, **2504***a*, **2504***b*, **2504***c* can be adjusted to form a variety of shapes including straight, curved, and more. For example, the adjustable linkages **2404***a-c* in FIG. **24**A can be formed from a coiled material or a plurality of linkage sections mated together. The linkages **2404***a-c* can also include a tensioning cable **2408** disposed within a central lumen of the adjustable linkage **2404**, as shown in FIG. **24**B. The tensioning cable **2408** can lock the adjustable member **2404** in a desired shape by squeezing each coil or linkage section together, thereby causing interference between them. A locking mechanism formed on a terminal end **2410***a*, **2410***b*, **2410***c* of the adjustable linkages **2404***a-c* can include a lever **2412***a*, **2412***b*, **2412***c* configured to both connect the terminal ends to support members **2406***a*, **2406***b*, **2406***c* and to tension any tensioning cables **2408** to lock the adjustable linkages **2404***a-c* in a desired shape.

FIG. **25** illustrates a similar embodiment in which the adjustable linkages **2504**-*c* include a plurality of linkage sections **2508** connected together. Linkage sections **2508** can have unique complementary geometries as known in the art to facilitate friction locking to allow the adjustable linkages **2504***a-c* to retain a desired shape or orientation. Adjustable linkages **2508***a-c* can, in some embodiments, also include an inner tensioning cable and a lever **2512***a*, **2512***b*, **2512***c* configured to any of connect the adjustable linkages **2504***a-c* to support members **2506***a-c* and tension any tensioning cable, as discussed above.

In some embodiments, a surgical support frame can be constructed including only two adjustable linkages to reduce the space required by the surgical support frame. An exemplary embodiment of such a surgical support frame is shown in FIG. **26**. The illustrated surgical support frame includes a first adjustable linkage **2604***a* and a second adjustable linkage **2604***b*. The frame includes three support members **2606***a*, **2606***b*, **2606***c* at each terminal end of the adjustable linkages **2604***a*, **2604***b*. In order to maintain the structural integrity of the surgical support frame without a third adjustable linkage connecting support member **2606***a* to support member **2606***c*, the adjustable linkages **2604***a-b* can be rigidly connected to support members **2606***a-c*. Each adjustable linkage **2604***a-b* can telescope in length or otherwise adjust, as discussed above. In some embodiments, the adjustable linkages **2604***a-b* can include features to better support the weight of any devices disposed in the support members **2606***a-c* without a third adjustable linkage. In embodiments having telescoping adjustable linkages **2604***a-b*, these features can include square, I-beam, or other cross-sectional shapes capable of bearing the weight of the support members **2606***a-c* without deforming. In another embodiment shown in FIG. **27**, the adjustable linkages **2704***a*, **2704***b* can include an additional connecting member **2708** extending between the adjustable linkages **2704***a-b* at a point along their length between their terminal ends. The connecting member **2708** can control the angle formed between the two adjustable linkages **2704***a-b*. In such an embodiment, the adjustable linkages **2704***a-b* can include a locking mechanism, such as a thumbscrew **2710***a*, **2710***b* that can be configured to selectively lock both the length of each adjustable linkage **2704***a-b* and the angle formed between the adjustable linkages.

In still other embodiments, the adjustable linkages can a rolling cam locking mechanism to selectively lock an adjustable linkage at a particular length. FIG. **28**A illustrates a surgical support frame having adjustable linkages **2804***a*, **2804***b*, **2804***c* with this type of locking mechanism. As shown in the figure, adjustable linkages **2804***a-c* have a rectangular cross-sectional shape with a rolling locking mechanism **2812***a*, **2812***b*, **2812***c*. Each rolling locking mechanism **2812***a-c* can include a non-symmetrical rolling pin mounted on a female linkage member **2814***a*, **2814***b*, **2814***c*. The rolling pin can protrude into a male linkage member **2816***a*, **2816***b*, **2816***c* in one configuration, thereby restricting the movement of the male linkage member **2816***a-c* within the female linkage member **2814***a-c*. In another configuration, the rolling pin can provide clearance such that the male linkage member **2816***a-c* can telescope with respect to the female linkage member **2814***a-c*. By moving the rolling pin between the two configurations, each adjustable linkage **2804***a-c* can be selectively locked at a desired length.

FIG. **28**A also illustrates another embodiment of a support member **2806***a*, **2806***b*, **2806***c* that includes an electrically actuated locking mechanism. As shown in the cross-sectional view of FIG. **28**B, each support member **2806***a-c* includes a top electromagnetic plate **2808** and a bottom electromagnetic plate **2810**. Upon application of a voltage from power source **2818**, the electromagnetic plates **2808**, **2810** can compress together causing interference with an inner receiving ball member **2802**, thereby restricting its movement. Each support member **2806***a-c* can also include controlling components to selectively actuate the electromagnetic plates **2808**, **2810**, or a controller can be included separate from the device, as is known in the art. Other embodiments of the surgical support frame may make use of alternative actuation mechanisms. By way of example, pneumatically actuated pistons can be configured to press a cap (similar to cap **812** discussed above) or linkage plate (similar to linkage plates **2808**, **2810**) onto the receiving ball member **2802** to restrict its motion. Still further, a receiving member (similar to receiving member **1002** discussed above) can be configured to adjust in size in response to manual, electric, or pneumatic actuation, thereby restricting the movement of a receiving ball (similar to receiving ball **802** discussed above) disposed therein. Utilizing electric or pneumatic actuation technologies can also allow for simultaneous locking and unlocking of multiple support members. All of these variations are considered within the scope of the present invention.

The embodiments described above provide devices capable of, for example, fixing a trocar cannula in a desired location and/or orientation with respect to one or more other trocars and the body of a patient. The surgical support frame of the present invention can also include devices configured to secure a surgical instrument extending through a trocar into the body of a patient. Using such a device, the surgical support frame can be configured to retain both the trocar and any surgical device inserted therethrough in a fixed orientation with respect to any other trocar or surgical device and the body of a patient. FIGS. **29**A, **29**B, and **29**C illustrate an exemplary device for fixing a surgical instrument with respect to a surrounding trocar. As shown in FIG. **29**A, the locking device **2902** includes a body **2904** having a central lumen **2906** configured to align with a central lumen of a trocar. The locking device **2902** also includes a lever **2908** configured to fix any surgical instrument extending through the central lumen **2906** with respect to the locking device **2902**. The locking device **2902** can further include one or more attachment clips **2910** with one or more release buttons **2912** configured to move the one or more clips **2910**.

As shown in FIG. **29**B, the locking device **2902** is in the form of a cap or housing that is configured to attach to the top of a surgical trocar, such as trocar **102** shown in FIG. **1**. The one or more clips **2910** are configured to engage with one or more complementary slots formed on the top surface of the trocar **102**. When in position, the central lumen **2906** of the locking device **2902** is in alignment with a central lumen of the trocar **102**. To remove the locking device **2902**, the one or more release buttons **2912** can be depressed to move the one or more clips **2910** and cause their release from the one or more complementary slots formed on the top surface of the trocar **102**.

When the locking device **2902** is disposed on top of a trocar and a surgical instrument is inserted through the central lumen **2906**, the lever **2908** can be used to fix the surgical instrument with respect to the locking device **2902** and the trocar. FIG. **29**C illustrates an exemplary mechanism for fixing a surgical instrument with respect to the locking device **2902**. As shown in the figure, lever **2908** pivots around an attachment pin **2914** and includes a shelf **2916** configured to push against a locking tab **2918** when the lever **2908** is pushed into the orientation shown in FIG. **29**A. In response to the pressure from shelf **2916**, locking tab **2918** can extend into the central lumen **2906** and press any surgical instrument disposed therethrough into the opposite wall **2920** of the central lumen **2906**. When the lever **2908** is returned to the orientation shown in FIG. **29**C, the shelf **2916** is rotated away from the locking tab **2918** (which can be spring loaded to retreat from the central lumen **2906**) which allows the surgical instrument disposed through the central lumen **2906** to move freely.

The surgical support frame of the present invention can be manufactured using a variety of materials. For example, the surgical support frame can be manufactured using various metals such as titanium or titanium alloys. In addition, the surgical support frame can be manufactured using any of a variety of polymers. In certain embodiments, surgical support frames constructed from biocompatible metals, polymers, or combinations thereof are preferred. Similarly, the surgical support frame of the present invention can be constructed in a variety of sizes. The size of the surgical support frame, and the magnitude of adjustment possible in components such as the adjustable linkages, can be varied according to intended use and user desire. In some embodiments, surgical support frames sized to rest stably on a human torso and provide adjustable access to various locations on a human torso are preferred.

In another aspect of the invention, methods of using a surgical support frame of the present invention are provided. In one embodiment, a surgeon or other user can position a surgical support frame on a skin surface of a patient. For example, a surgeon can position a surgical support frame on top of the stomach of a patient when the patient is lying supine in an operating room. The surgeon can optionally be provided with a kit of support members and linkages, allowing the surgeon to construct a support frame having the desired number of supports at desired locations.

The surgeon or other user can manipulate a first surgical instrument extending through a first cannula that is mounted on the surgical support frame to position a distal end of the first surgical instrument within a body cavity. With the surgical instrument is in a desired position, the surgeon can lock the first cannula in a fixed position and/or orientation relative to the support frame, thereby locking the cannula in a fixed orientation relative to the body of the patient. The surgeon can also manipulate a second surgical instrument extending through a second cannula mounted on the surgical support frame to position a distal end of the second instrument within a body cavity. Following positioning of one or more surgical instruments, the surgeon or other user can lock at least one of the first and second cannulas in a fixed position and/or orientation relative to the support frame such that at least one of the first and second surgical instruments is maintained in a desired fixed position. Having locked one or more of the first and second surgical instruments in a fixed position and/or orientation with respect to each other and the patient, the surgeon or other user can manipulate a third surgical instrument extending through a third cannula mounted on the surgical support frame to position a distal end of the third surgical instrument within a body cavity. This process can be repeated for as many support members as the frame may have. By providing the surgeon or other user with a way to secure the position and/or orientation of one or more surgical instruments, the surgical support frame of the present invention allows the surgeon to more efficiently control the various instruments required during a laparoscopic procedure without the need for additional surgeons, assistants, etc.

In another aspect of the invention, a surgeon or other user can position a surgical support frame of the present invention on a skin surface of a patient (e.g., on the stomach or torso of a patient). The surgeon can then move at least one of the support members of the surgical support frame to adjust an effective length (i.e., a length between the terminal ends of the adjustable member) of at least one of the adjustable linkages of the surgical support frame. Adjusting the effective length of one or more of the adjustable linkages can allow the surgeon to position one or more surgical instruments at one or more desired locations on the skin surface of the patient and, accordingly, at one or more desired locations within a body cavity of the patient. The surgeon or other user can also or alternatively angularly adjust at least a portion of at least one of the support members of the surgical support frame relative to the connected telescoping linkages. For example, a cannula extending through the support can be angularly adjusted to thereby cause either a ball through which the cannula is disposed to move polyaxially, or to cause the entire support member to pivot or angulate relative to the linkages coupled thereto. Angularly orienting the support members can further aid in positioning one or more surgical instruments at one or more desired locations on the skin surface of the patient and/or within a body cavity of the patient.

Following or during positioning of the various support members of the surgical support frame, the surgeon or other user can lock at least one of the adjustable linkages to retain the selected effective length of the linkage. In addition, the surgeon or other user can lock at least one of the support members to retain the selected angular orientation of the support member or cannula or instrument extending therethrough. By locking the adjustable linkages and support members in a desired position, the surgical support frame can retain one or more cannulas (e.g., surgical trocars) and/or surgical instruments in a desired position and/or orientation relative to each other instrument inserted through the frame. Furthermore, because the surgical support frame rests on a patient, the surgical devices are also held in a fixed position and/or orientation with respect to the body of the patient.

The devices disclosed herein can be designed to be disposed after a single use, or they can be designed to be used multiple times. In either case, however, the device can be reconditioned for reuse after at least one use. Reconditioning can include any combination of the steps of disassembly of the device, followed by cleaning or replacement of particular pieces, and subsequent reassembly. In particular, the device can be disassembled, and any number of the particular pieces or parts of the device can be selectively replaced or removed in any combination. Upon cleaning and/or replacement of particular parts, the device can be reassembled for subsequent use either at a reconditioning facility or by a surgical team immediately prior to a surgical procedure. Those skilled in the art will appreciate that reconditioning of a device can utilize a variety of techniques for disassembly, cleaning/replacement, and reassembly. Use of such techniques, and the resulting reconditioned device, are all within the scope of the present invention.

All papers and publications cited herein are hereby incorporated by reference in their entirety. One skilled in the art will appreciate further features and advantages of the invention based on the above-described embodiments. Accordingly, the invention is not to be limited by what has been particularly shown and described, except as indicated by the appended claims.

What is claimed is:

1. A surgical support frame, comprising:

at least three support members connected to one another by at least three independently adjustable linkages arranged around a perimeter of an enclosed shape, each support member having a lumen extending therethrough for receiving a cannula, and each support member being configured such that a cannula extending through one of the at least three support members can be locked in a transverse angular orientation relative to a cannula extending through another one of the at least three support members, and such that a distance between each of the at least three support members is independently adjustable.

2. The surgical support frame of claim **1**, further comprising a locking mechanism associated with at least one of the at least three support members for locking at least one of the at least three support members such that a cannula extending through one of the at least three support members is retained in a desired angular orientation relative to a cannula extending through another one of the at least three support members.

3. The surgical support frame of claim **1**, wherein each support member is movably connected to at least one of the at least two adjustable linkages by ball and socket joints.

4. The surgical support frame of claim **1**, wherein the at least three support members comprise first, second, and third support members, and wherein the adjustable linkages are arranged to define a perimeter of a triangle.

5. The surgical support frame of claim **1**, wherein the at least three support members comprise first, second, third, and fourth support members, and wherein the adjustable linkages are arranged to define a perimeter of a square.

6. The surgical support frame of claim **1**, further comprising a locking mechanism associated with at least one of the at least two adjustable linkages for locking at least one of the at least two adjustable linkages at a desired length.

7. A surgical support frame, comprising:

first, second, and third support members, each having a lumen extending therethrough that defines a central axis, and each support member being configured such that the orientation of the central axis of the lumen is adjustable relative to the central axis of the lumen of another one of the support members;

a first linkage rod extending from the first support member directly to the second support member;

a second linkage rod extending from the second support member directly to the third support member; and

a third linkage rod extending from the first support member directly to the third support member,

wherein at least one of the first, second and third support members includes a locking mechanism configured to retain the central axis of the lumen of the support member in a desired orientation relative to the central axis of the lumen of another one of the support members.

8. The surgical support frame of claim **7**, wherein a length of each of the first, second, and third linkage rods can be adjusted.

9. The surgical support frame of claim **8**, wherein at least one of the first, second, and third linkage rods includes a locking mechanism configured to lock the respective linkage rod at a desired length.

10. A surgical support frame, comprising:

at least three support members connected to one another by at least two adjustable linkages, each support member having a receiving member, a cap, and a receiving ball disposed between the receiving member and the cap such that the receiving ball can move poliaxially relative to the support member,

wherein the receiving ball includes a lumen formed therein for receiving a cannula, and wherein the cap is configured to move relative to the receiving member to selectively inhibit the poliaxial movement of the receiving ball, and

wherein a length along a longitudinal axis of each adjustable linkage extending between proximal and distal ends thereof can be adjusted.

11. The surgical support frame of claim **10**, wherein the surgical support frame comprises at least three adjustable linkages and wherein the at least three adjustable linkages are arranged to define a perimeter of an enclosed shape.

12. The surgical support frame of claim **11**, wherein the at least three support members comprise first, second, and third support members, and wherein the adjustable linkages are arranged to define a perimeter of a triangle.

13. The surgical support frame of claim **10**, further comprising a locking mechanism associated with at least one of the at least two adjustable linkages for locking at least one of the at least two adjustable linkages at a desired length.

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